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AIR FORCE SPECIAL WEAPONS CENTER

AIR RESEARCH AND DEVELOPMENT COMMAND

KIRTLAND AIR FORCE BASE, NEW MEXICO

Technical Note

THE FEASIBILITY OF USING REMOTELY CONTROLLED VEHICLES TO DECONTAMINATE LARGE PAVED AREAS

by

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ABSTRACT

Studies were performed to determine the feasibility of using a remotely controlled vehicle to sweep and remove radioactive debris from large paved areas. Test data were collected for comparison of the remote operation and manual operation of the vehicle. The test parameters included comparison of (1) decontamination efficiency, (2) time needed for decontamination, and (3) sweeping patterns.

A comparison of test parameters has indicated that it is feasible to use a remotely controlled sweeper to decontaminate an area. Approximately the same decontamination efficiencies were obtained under remote and manual operation (approximately 99.7 percent). The operating time for remote decontamination was about twice that for manual. This time can be reduced as the area to be swept becomes larger and the operator becomes more proficient. These results were obtained on a small area (approximately 3,000 square feet). The time lost was mostly in turning around and reorienting the vehicle at the end of each sweeping pass on the contaminated area.

The driving patterns were quite different. Under manual operation, the vehicle is easily controlled and no sweeping overlap is necessary. Under remote operation, there was a tendency for the vehicle to drift. The operator, attempting to correct this, had a tendency to oversteer, which resulted in more sweeping passes than were necessary. Refinement of the remote steering mechanism would correct this discrepancy.

PUBLICATION REVIEW

This report has been reviewed and is approved.

CAREY L. O'BRYAN, JR.
Colonel USAF
Deputy Commander

ACKNOWLEDGMENTS

The authors wish to express their thanks to the Naval Radiological Defense Laboratory, San Francisco, California, for cooperation in the execution of these tests. Particular appreciation is expressed for the special efforts of Mr. Don Clark who facilitated the completion of the tests. The testing phases were conducted under the direction of the 4925th Test Group (Atomic), Kirtland AFB, New Mexico. Data reduction was performed by Mrs. H. L. Douglas, Biophysics Division, AFSWC.

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I. PURPOSE.

The purpose of these studies and tests was to determine a possible method for removal of radioactive debris from large paved areas following a nuclear detonation. It must be anticipated that a nuclear detonation--either a near miss or a distant explosion--could result in radioactive contamination of high intensity. The radiation intensity could be of such magnitude that it would prevent an operator from entering the field and performing manual decontamination. Operational necessity requires immediate removal of the contaminant, thus excluding the possibility of a time delay to permit natural decay of the radioactive elements.

This study was conducted under ARDC Technical Requirement 153-56 to investigate the use of automatic decontamination devices and methods for runway and ramp areas.

II. INTRODUCTION.

With the advent of high-yield nuclear weapons, thought has been given by the Air Force to the removal of vital installations into protective shelters. These shelters, immune to blast, shock, and radiation, would provide adequate protection internally, but could be located in such places that the resultant fallout radiation intensities externally could be very high. The use of the exterior work areas of such an installation would be prohibited until such time as the level of the radiation was reduced to tolerable limits for personnel activities.

Although experimental evidence has indicated that an area exposed to moderate-to-severe structural damage will not be subjected to fallout for approximately 1 hour, it is not anticipated that any significant amount of cleanup could be accomplished during this period because of the disorder and confusion which would follow the catastrophe. Consequently, it is probable that some cleanup of debris would have to be accomplished in the presence of fallout.

These studies and tests resulted from the Air Force requirement to determine a feasible method of returning a tactical installation to an operational status following a nuclear attack. For retaliatory purposes, it is desirable that the installation be returned to an operational status at the earliest possible time.

Studies were made to determine the earliest time that decontamination procedures could be instituted. This time was established as the time of cessation of the fallout resulting from the detonation. In all cases where the site was at a "close-in" location, the time of cessation of the fallout revealed radiation intensities of a very high degree.

Since recovery of an installation at the earliest time is of paramount importance, it is not possible to expect personnel entry into high-intensity areas at these early periods. Under the conditions encountered, a lethal dose of radiation could possibly be acquired in a matter of a few minutes. Even with the application of the maximum permissible wartime dose, this limit would be reached in such a short time that no work capacity of an individual could be expected and no direct manual decontamination could be executed. (See table 1.)

Various methods of protection were investigated; the most logical was the shielding of the operator's position on decontamination equipment, but this proved unsatisfactory in high-intensity areas. This is explained more fully later.

Table 1

T ADIATION DOSE RECEIVED IN CONTAMINATED AREA[1]

Time of entry	Total dose received (roentgens)	If Radiation at H+1 hour is: 1,000 r/hr	10,000 r/hr
H+1 hour	100	8 min	<1 min
	200	16 min	< 3 min
H+3 hours	100	24 min	< 3 min
	200	55 min	4 min
H+1 day	100	5½ hrs	30 min
	200	12 hrs	1 hr

Since it was not possible to provide a method to protect decontamination workers for actual entry into the irradiated areas, the next step was to devise a means of controlling the decontamination equipment from a point where adequate protection could be afforded the operator. This led to the

installation of remote guidance facilities on decontamination equipment and to the subsequent preliminary studies and tests reported in this document.

The vehicle chosen for testing the concept of remotely controlled decontamination was a modified version of the Model 100 vacuum street sweeper built by the G. H. Tennant Company, Minneapolis, Minnesota. Equipped with a radio guidance system and television cameras, the sweeper was designed to clear a 7½-foot path of radioactive debris ranging in size from more than 2 inches to less than 5 microns in diameter with an efficiency of better than 99 percent. The material removed is then transported to a remote area and dumped in a predetermined location with the vehicle still under remote control.

Using the television system, an operator may survey the surrounding terrain so that a damage survey can be made in conjunction with the cleanup operation. The remote operation of the sweeper is controlled from a protected duplicate of the manual controls. The operator sits at a console, similar to a telephone switchboard, on which are mounted the controls with which he can perform more than a score of different functions. By pushing buttons, flipping switches, pressing pedals, or nudging sticks, he can steer the vehicle, shift gears, move the throttle, operate the brakes, empty the sweeper, and perform a number of other operations.

The material presented in this report is not complete, since the studies made were preliminary and directed toward determination of the feasibility of this type of operation.

The preliminary test results reported herein were obtained from testing performed at Camp Parks, California, in conjunction with experiments being performed by the Naval Radiological Defense Laboratory, San Francisco, California.

III. DISCUSSION.

A. History of project.

Prior to the studies and tests conducted on the remotely controlled decontamination sweeper, extensive surveys were made to determine which of several methods of decontamination could be employed most feasibly. In

each of the methods of decontamination investigated, consideration was given to various factors involved, including

1. Efficiency of operation in contaminant removal.

2. Adaptability of operation to contaminated site and geographical location.

3. General economy of operation.

4. Applicability to both low and very high radiation intensity areas.

5. Personnel hazards involved in operation.

6. Vulnerability to aggressive action.

These were the general areas considered. It is recognized that for special applications, other factors could be involved. The factors are not in order of importance, this again being determined by the specific application.

An attempt was made to find a decontamination method that would prove satisfactory under all the conditions listed above. Investigation of work and experiments done by other agencies with similar interests revealed that no completely satisfactory procedure or equipment had been evolved at that time. However, all previous ways were considered with the idea that some method or combination of methods could be compounded into an acceptable system. Following are examples of the techniques investigated and the primary reasons why each was discarded in lieu of the subsequent development of a remotely controlled vehicle type of operation. Each method is summarized and data in many instances were gathered from reports of more detailed tests conducted by other agencies. It must be kept in mind that the prime requisite of the desired system was that it be acceptable in radiation fields of very high intensity, covering an extensive area. The decontamination was required for hard surfaces only (asphalt paving, concrete, etc.), and only dry contaminants were considered.

B. <u>Decontamination systems investigated</u>.

1. Land washdown systems.

This system was primarily considered in that it could lend itself to unmanned operation and had the possibility of being adapted into a fully automatic system.

Washdown procedures in the radiation areas involved in this study presented many more problems than had been originally anticipated. In all instances where testing of this type was conducted, however, the contaminant removal efficiency proved satisfactory--95 percent or better. The techniques required to attain this efficiency were in most cases adverse to the requirements of the acceptable system outlined in this study.

a. Vast quantities of water are required. Available data indicate that it takes approximately 1.4 gallons of water for every square foot of area that is decontaminated[2]. In places where 1,000,000 square feet or more of surface may require decontamination, the quantity of water necessary would be prohibitive. In areas where a fresh water supply was not available, storage facilities would have to be quite large, even if a recirculating system could be devised.

b. Special construction would have to be employed. Since most areas used by Air Force equipment are normally constructed on a level plane, washdown would not be sufficiently effective. A definite slope is needed for proper drainage to maintain a water velocity great enough to suspend the particulate being removed until it reaches a sump or disposal location. These sumps would also require special construction so as to be strategically spotted for contaminant collection.

c. Plumbing systems would be extensive. The water dispersal system would have to be large enough to provide adequate coverage of the contaminated areas.

d. The complete washdown system would be very vulnerable to blast. Even if ground displacement were small, numerous system ruptures could be anticipated.

e. The cost of an adequate system would be prohibitive.

For these reasons, and others not itemized here, further investigation into more acceptable systems was made.

2. Vehicle shielding.

After a washdown system was discarded as a means of automatic land decontamination, attention was again directed to operations that would

require manned equipment. In the radiation areas of interest, it was obvious that some type of operator protection would be required to permit prolonged work periods. This led to consideration of constructing shielded cabs in the operator's position on earth-moving type of equipment[3].

The first step in the decontamination of an area would be the removal of large amounts of debris which would range in size from minute particles to boulders of large diameter. Bulldozer or grader-type machinery would be necessary to move the larger masses to a reasonable distance, so that only material from a few microns to an inch or so in size remained. This could be removed by a street-sweeper type of vehicle capable of retaining this material internally for transportation and disposal at an appropriate location.

The Caterpillar Tractor Company[4], manufacturer of one type of debris-moving equipment, was queried as to the ability of bulldozers and graders to support appropriate shielding. Estimates for the maximum cab weights which were recommended for the various tractors are as follows:

Tractor	Weight
D4	5,000 lbs
D6	6,500 lbs
D7	8,250 lbs
D8	10,000 lbs

These weights were for proposed cab sizes which would be of minimum adequacy for operator comfort and would give sufficient room for manipulating the various tractor controls.

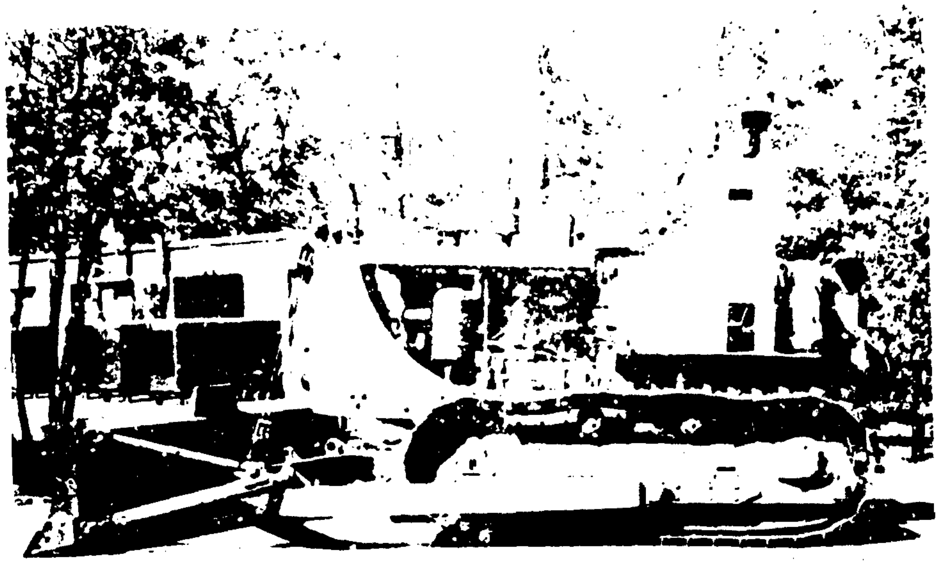
The use of 1-inch lead in the floor area and the sides of the cab and 1/2-inch lead for the cab top would allow the weights of these various cabs to fall within the cab recommendations. It would not be desirable to mount the cabs directly to the deck structure, but supports could be built on the tractor main frame and bevel gear cases to support the added weight. Some relocation work, such as moving controls to bring them into the cab area through pivoting shafts, would be required. This would eliminate the necessity for providing slotted clearance holes, and thus prevent radiation leakage. Some of the instruments would require relocation for operator

Figure 1. Shielded cab on ERDL tractor.
US Army Photo

visibility within the cab. The possibility of having to do some redesign work on fuel tanks, air cleaners, deck members, etc., also existed.

On the motor graders, cabs similar in design to the regular cabs could be constructed and supported satisfactorily. It was suggested by Caterpillar that a cab of 8,000 pounds could be supported without any detrimental effect to the motor grader.

Considerable research has been done by the US Army Engineer Research and Development Laboratory, Fort Belvoir, Virginia, on the protection of equipment operators by shielding[5]. Tests have indicated that the lead cabs as previously described can provide a reduction of up to 95 percent of the radiation intensity of test fields. While this is a significant reduction, and satisfactory for low-intensity fields, the remaining 5 percent of the radiation in a field of 5,000 to 10,000 r/hr would still result in 250 to 500 r/hr. This dosage would prevent sustained operations, even with frequent change of operators, since the time necessary for entering the field and returning would use up a major portion of the permissible work period

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of each individual. In addition, the contamination level of the vehicle could be great enough that its return to the area of operator transfer would be prohibited.

The psychological factor involving the operator in these high-intensity areas would also be a limiting factor. A man inclosed in a sealed cab and sent into areas where a mechanical malfunction could possible cause his death may be handicapped in his working capacity by this knowledge. This, plus his cognizance of the radiation dose he is receiving, might reduce his working ability to a point where no appreciable results could be obtained.

Further studies on shielded equipment for use in high-radiation areas were discontinued. It must be remembered that although it was determined that this approach is not feasible in high-intensity regions, the use of shielded equipment in low-intensity areas could prove quite valuable and is most likely the best approach for the decontamination of these areas.

Tables 2 and 3 are extracts from the USAERDL report to show the protection that can be obtained from the construction of protective cabs for some heavy equipment. Shielded equipment could satisfy most of the requirements listed in section III of this report for high-level work, but in reiteration, the protection factor supplied by the permissible shielding limits their use to radiation fields of lower intensity than those of primary interest.

3. Remotely controlled motorized equipment.

a. Introduction and background.

During the course of investigating the preceding decontamination methods, it was decided to concentrate the studies on remotely controlled equipment: specifically, a waterless, vacuum-equipped, street-type sweeper. Justification for this remotely controlled device was the critical factor of radiation exposure of the decontamination crews. Crews which would be required to conduct manual operations could not commence until natural decay of the fallout radiation had lowered dose rates to a reasonable level. This delay could be several weeks or more, while resumption of activities at a particular Air Force site may be necessary within a few hours. (See table 1.)

Table 2

PROTECTION FACTORS FOR A PROTOTYPE LEAD CAB
FOR D8 DOZER IN 300-YARD RADIUS CO-60 FIELD

LEAD THICKNESS (inches)					PROTECTION FACTOR* OPERATOR POSITION	
Lower	Upper	Roof	Seat	Floor	Abdomen Height	Head Height
0	0	0	0	0	1.9	1.5
1/4	0	0	1/4	1/4	2.9	1.6
1/4	1/4	0	1/4	1/4	2.9	2.4
1/2	0	0	1/2	1/2	3.5	1.6
1/2	1/2	0	1/2	1/2	4.5	3.2
1	1/2	0	1	1	8.1	3.6
1	0	0	1	1	5.9	1.7
1	1	0	1	1	8.7	5.8
1	1	1/4	1	1	9.7	5.9
1	1	1	1	1	9.4	7.2

$$*\text{Protection factor} = \frac{\text{free field dose rate at 3 feet}}{\text{inside dose rate at measured height}}$$

Table 3

PROTECTION FACTORS FOR A #12 GRADER WITH
PROTECTIVE CAB IN 300-YARD RADIUS CO-60 FIELD

LEAD THICKNESS (inches)					PROTECTION FACTOR OPERATOR STANDING	
Lower	Upper	Roof	Seat	Floor	Abdomen Height	Head Height
0	0	0	0	0	2.1	1.4
1/4	0	0	1/4	1/4	2.6	1.8
1/4	1/4	0	1/4	1/4	3.0	2.1
1/2	1/2	0	1/2	1/2	5.2	3.1
1	1/2	0	1	1	---	5.1
1	1	0	1	1	10.9	7.1
1	1	1/4	1	1	12.4	8.9
1	1	1	1	1	12.6	8.4

The need for decontamination of large areas promoted the use of a motorized sweeper. Since the fallout particulate with which most of the radiation would be associated would be of fairly small size, a sweeping

method with complete retention of the particles was required. It was believed that the complexities of a sweeping-type vehicle could provide a typical application of the proposed system; then other required vehicles could be patterned after this particular system. The sweeper therefore would be the most apt point to start the application. About the same time the decision was made to concentrate research on sweeper-type equipment, a requirement from ARDC was presented to the Air Force Special Weapons Center to investigate the use of a vacuum sweeper for use as a decontamination vehicle.

b. Sweeper requirements.

The requirements as set forth by ARDC were that the sweeper would consist of a large four-wheeled vehicle with a shielded cab area for the operator. The equipment was to consist of a broom, a high-efficiency vacuum system, and a shielded container for storage of debris collected from the contaminated area. It was to be capable of decontaminating approximately 500, 000 square feet of concrete in 1/2 hour, with a 90 percent efficiency of removal of dry contaminant.

c. Review of available equipment.

(1) Coleman runway vacuum sweeper.

The requirements from ARDC closely paralleled the specifications of the Coleman Runway Vacuum Sweeper developed by the Coleman Engineering Company, Inc. of Los Angeles, California (see figure 3). The feasibility of shielding the operator's cab had already been studied and found impractical. Depending upon material used and space required for the operator, an added weight of 6, 000 to 20, 000 pounds would be required. This might be used in some instances on heavy equipment, but would seriously impair the operation of a relatively light vehicle.

Investigation of the Coleman sweeper indicated that extensive modification to the unit would be necessary to make it suitable for decontamination purposes. The US Naval Civil Engineering and Research Evaluation Laboratory at Port Hueneme, California, had initiated a study contract with the Coleman Engineering Company to determine the feasibility of adapting the Coleman-designed airfield vacuum cleaner for use in effectively decontaminating paved areas.

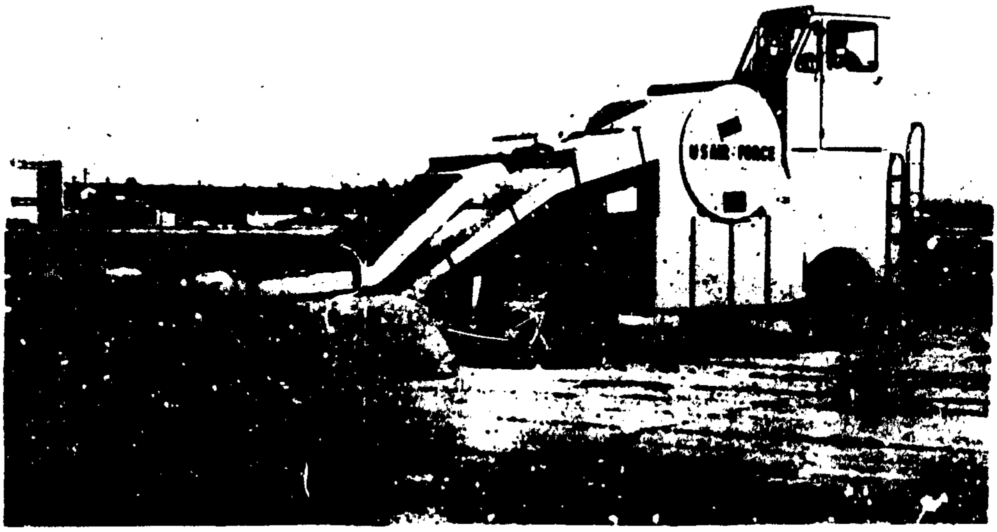


Figure 3. Coleman runway vacuum sweeper.

From the conclusions of the Engineering Status Report[6] prepared by the Coleman Company the following information was drawn:

> Separation of contaminant is a multi-stage operation. The standard Cole-Vac separation apparatus will remove 58%±10% of the entrained dust. The remainder is discharged through the air bleed-off port and must be separated by supplemental separation machinery. Commercial machinery capable of separating the entrained dust from the bleed-off air to meet decontamination specifications is so large and unwieldy that it is not suitable for use in a mobile unit.
>
> Specially designed, high efficiency cyclone separators are reportedly available which, if used in series with intermediate cyclones of commercial type, can handle the volume and density load and separate and retain the entrained dust to specified 99%. This combination, together with the intermediate stage fan and motor necessary to maintain functional velocity in the air-stream, can be mounted on a large trailer and towed by the standard Cole-Vac. Flexible ducting can be installed between the two vehicles.

To accomplish the required mission, it would be necessary to lengthen greatly the present Cole-Vac sweeper by the addition of a large trailer attached to the sweeper. It appears from the Engineering Status Report that a brush assembly should be added in front of the sweeper and a series of cyclone separators to the rear. The Cole-Vac sweeper has an overall length of 30 feet. The separator system added to the rear would increase the length approximately another 30 feet. In addition, the broom system attached to the front of the vehicle would increase the length still another few feet.

Because an extremely large vehicle would be necessary to attain the 99 percent efficiency and because of the extremely high cost of all the necessary machinery to make the Cole-Vac suitable for decontamination work, the vehicle was eliminated from AFSWC consideration as a possible decontamination sweeper.

The US Naval Civil Engineering Laboratory, Port Hueneme, California, further substantiated AFSWC's opinion in their Technical Note[7] with this statement:

> NCEL work on pavement decontamination was initiated with a feasibility study contract with the Coleman Engineering Company on a high speed runway vacuum sweeper... This study resulted in a determination that the Coleman runway vacuum sweeper could not economically be converted for decontamination sweeping.

(2) Tennant Model 100 sweeper.

Continued investigation led to the discovery of the Model 100 vacuum sweeper built by the G. H. Tennant Company of Minneapolis, Minnesota. Preliminary studies indicated that this sweeper was of the type which could be easily converted into an excellent decontamination unit. The Tennant Company demonstrated to AFSWC personnel the pickup capabilities of the Model 100. The following objects were spread in a 3-foot path 20 feet long:

2 Coke bottles
1 beer can
10 pounds of rock, pea gravel to 2-inch size
2 boards, 1 x 4 x 12 inches
10 1/2-inch I. D. aluminum washers

10 1/2-inch I. D. steel washers
5 1/4-inch 28NF 2-inch bolts with nuts detached, aluminum
5 1/4-inch 28NC 2-inch bolts with nuts detached, steel
5 5/8-inch 14NC 3-inch bolts with nuts detached, steel
3 Vellumord gaskets

The sweeper demonstrated 100 percent pickup of the objects. A standard production-line Model 100 was purchased to perform experiments to determine its effectiveness for decontamination of hard surfaces. Tests were conducted in conjunction with a series of decontamination experiments performed in September 1958 by the Naval Radiological Defense Laboratory at Camp Stoneman, California. These initial tests indicated that the sweeper would perform satisfactorily. A complete description of the Tennant 100 and a thorough analysis of the test data, as well as the same information for other sweepers, appear in USNRDL-TR-336[8] and USNCEL N-376[7].

(3) ARDC-Tennant 100DS sweeper.

The field testing at Camp Stoneman indicated certain modifications were necessary for the Model 100 if it were to meet all the specified requirements. A contract was initiated with the G. H. Tennant Company to incorporate all these modifications into a prototype model suitable for remote controlling. This will be referred to as the Model 100DS.

(a) Design specifications of the Model 100DS.

After a detailed study of the Model 100, the improvements considered necessary in the construction of the 100DS were compiled and submitted to the contractor. The general outline of requirements listed in the Statement of Work was as follows:

> The sweeper will be a dual purpose sweeper which will be used during periods of emergency following a nuclear detonation as a decontamination sweeper, and during non-emergency periods as an aircraft ramp and taxiway cleaner.
>
> The sweeper will be capable of decontaminating up to 600,000 square feet of concrete or asphalt surface per hour with a minimum of 98% efficiency on dry contaminants. It will have very high maneuverability, enabling it to operate around parked aircraft, or in small areas where decontamination must be effected. Its over-all dimensions will be such that air transportation can be provided in present Air Force cargo type aircraft of the C-124 type.

Figure 4. Tennant model 100 vacuum sweeper.
G. H. Tennant Photo

> As a decontamination sweeper it will be used to decontaminate operational areas contaminated by radioactive debris resulting from a nuclear detonation. It will be capable of retaining particles of less than 5 microns in size, and as shown in recent operational service tests, capable of decontamination of a high degree of efficiency.
>
> As a sweeper for taxiways and ramps, it will be effective in picking up and retaining large size foreign objects which could be drawn into jet type aircraft engines. The small and large particles will be picked up and retained in one operation.

Some of the more detailed areas defined for incorporation into the 100DS Sweeper were the following:

> Decontamination efficiency of the Model 100, even though exceptionally good, can be improved by addition of greater vacuum and air agitation.
>
> Quantity of material retained can be increased to give longer operational periods between emptying.

Figure 5. ARDC-Tennant model 100DS vacuum sweeper.
G. H. Tennant Photo

Sweeping capabilities can be increased to decrease the time required to clean a given area.

In addition to the above improvements, it is desirable to equip the sweeper for completely remote control operation. This is necessary so that during decontamination operations, when it is not possible to send an operator into high radiation areas, the decontamination procedures can be completed without delay.

The sweeper must conform to the present Model 100 in regard to performance, equipment, and operation as closely as possible.

Main broom will have a length of approximately 8 feet, or as close thereto as a maximum machine width of 8 feet will allow.

Hopper capacity will be approximately 4 cubic yards, with interior contours designed to allow clean, complete dumping.

Pickup system will be devised to facilitate decontamination capabilities by:

Installation of air jets in close proximity to main broom to bring into air suspension the small particles not removed by broom, which will be collected by the vacuum system.

Installation of air jets along side of broom to control "trailing."

Installation of two engines instead of one. One engine will drive vacuum system, brushes, and other such equipment, and the second engine will provide the power for propulsion.

Engines will be equipped with automatic chokes and designed for all weather operation.

The propulsion engine will be equipped with a torque converter transmission and equipped with such speed-selection mechanisms as to allow four forward speeds, neutral and reverse.

The electrical system will be 24-volt, shielded to meet radio interference suppression specification MIL-S-10379A, non-tactical use. A 24-volt DC generator power source having a capacity of 150 amperes will be used to supply power for the remote control, television and other radio equipment.

Adequate lighting, front and rear, will be provided for day or night remote operations.

The hydraulic, electrical, and mechanical systems will be equipped with the proper valves and/or solenoids necessary for remoting the equipment. The electrical circuits for the remote operations will terminate in a suitable weather-proof receptacle into which the remote equipment can be plugged.

As many combined operations as are practical will be incorporated in the remoting of the vehicle so that remote operator training can be kept to a minimum. One example of joint operation is the combined shaking and dumping in such a manner of time delay sequence that the shaker will operate for approximately 30 seconds, and will cease as the hopper is closed, resetting itself for another cycle of operation.

An automatic cut-off system will be employed so the engines will be shut off and the brakes applied should adequate radio signal not be received.

Sufficient fuel capacity and other requirements will be provided to allow for 12-hours continuous operation without need for servicing or adjustment.

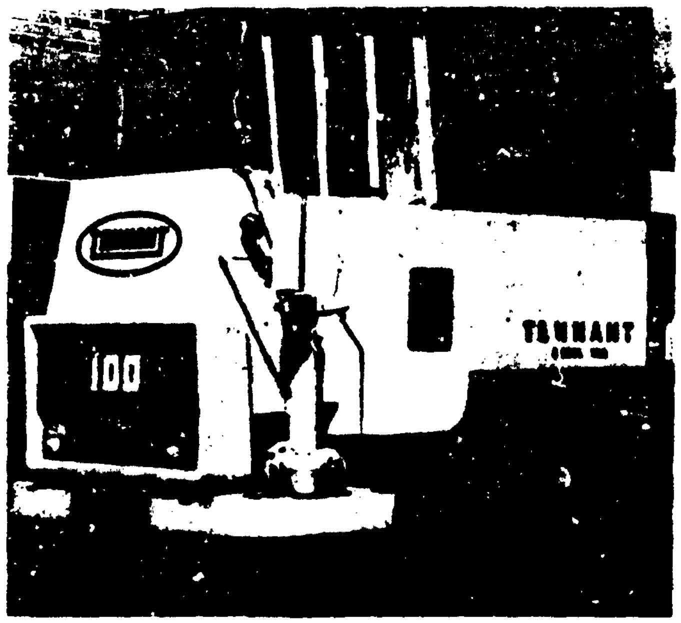


Figure 6. Model 100DS with hopper open.

Concurrently with the contract for the sweeper, a contract was initiated with the Custom Electronics Company, El Paso, Texas, to provide the guidance system for the vehicle. This equipment is used specifically to remotely operate the sweeper and provide voice communication between the sweeper and the control center.

The visual control equipment consists of a television transmitting and receiving system by means of which constant visual contact can be maintained with the area being decontaminated. The television equipment is used as the "eyes" of the vehicle. In addition, a radio link is maintained between the sweeper and the control center utilizing a tone modulation system for function control and operation of the vehicle.

(b) Technical discussion of Model 100DS.

The operation of the sweeper is very much like the operation of a home vacuum sweeper. Specially designed, crimped-steel-wire brushes dislodge and carry the large-size residue into the hopper. At the

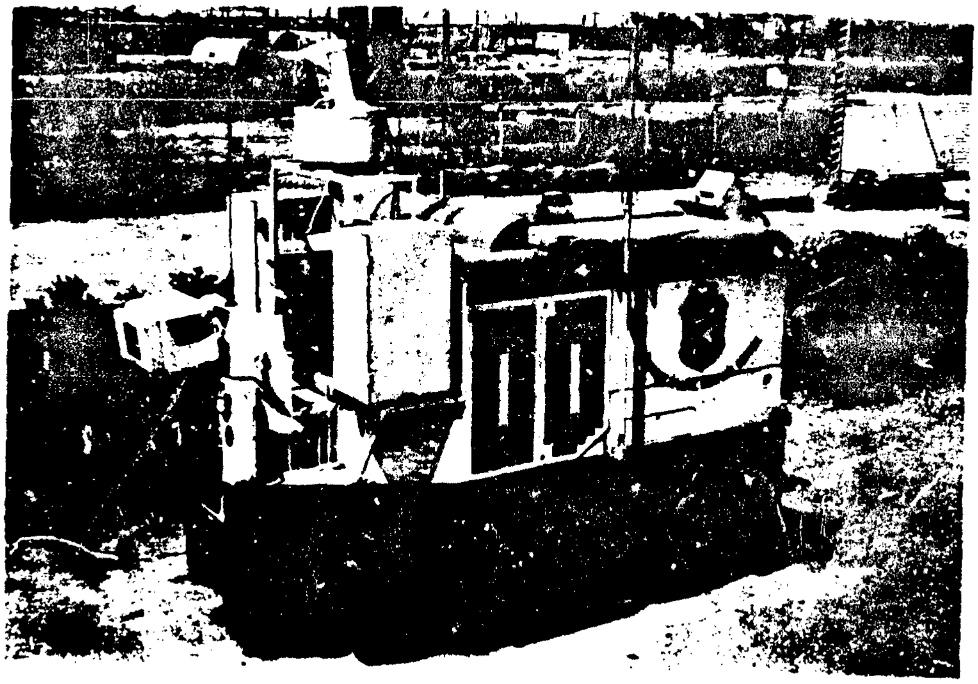


Figure 7. Remote controlled model 100DS sweeper.
US Navy Photos

same time, these rotating brushes scour the surface and bring into suspension the small particles, where the airstream from the vacuum system carries them to the filter bags where they are removed from circulation by the filters prior to the air discharge. These filters are capable of removing particles as small as 5 microns in size. Immediately behind the brushes is a row of air jets, spaced 1 inch apart, which dislodge the very small particles which might be lying in the small pits and crevices of the surface being cleaned. The high velocity air jets agitate the materials into suspension so that they can be removed by the vacuum system. (See figure 8.) In this manner removal and retention of greater than 99 percent of the radioactive particles are possible. Tests made on a Model 100 having the same type of filtration system showed that there was such a small amount of material discharged from the air outlet that it was not measurable and could be completely neglected.

Once the hopper is filled to capacity, emptying at a designated spot is an automatic operation. A clockwork timing mechanism performs the following functions in the proper order when activated:

1. Engine is advanced to full throttle to provide adequate hydraulic pressure.

2. The shaker mechanism is engaged. This shakes and agitates the filter bags so that all the fine residue deposited on them by the vacuum airstream is dislodged and shaken into the main hopper.

3. The hopper is opened fully to allow the debris to be emptied.

4. The hopper is partially closed and opened again rapidly to "bump" loose any material that may not have been emptied.

5. Throttle is retarded to idle.

The sweeper is now ready to continue its decontamination procedures.

The remote control of all functions of the vehicle is possible through modulated radio links. An RF carrier of the 450-460 megacycle range is used. This carrier is provided by a Kaar TR-500 transceiver installed at the control point with a similar transceiver located on the vehicle. The transmitting portion at the control point is keyed

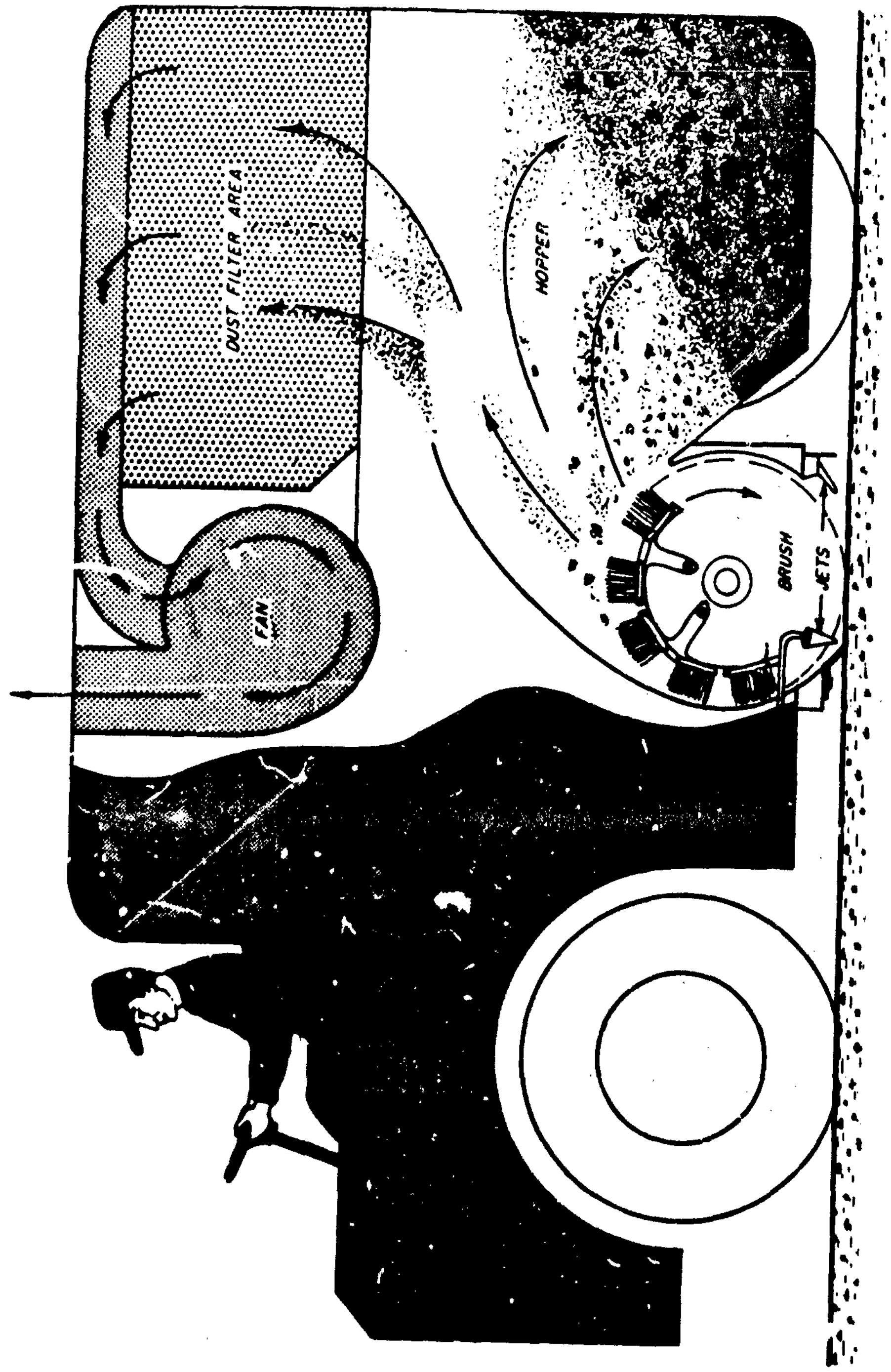


Figure 8. Diagram of sweeping system on model 100DS sweeper.

continuously as long as power is provided to the unit. This continuous carrier provides for an immediate response to all desired functions upon proper signaling. It also provides a "dead-man" circuit should the power to the transmitter be lost, electronic malfunction of the transmitting-receiving components occur, or should there be a physical interference with the RF carrier between the control center and the remote equipment. A physical interference may be in the form of terrain clearances, buildings, or debris as the vehicle moves about the work area. It must be remembered that the utilization of the UHF frequencies in this remote application results in relatively "line-of-sight" type of transmission. If the vehicle enters a depression or goes behind a rise in the ground level, attenuation of the carrier signal below the minimum allowable reception level would occur and the dead-man circuit would be activated. This dead-man circuit provides for automatic emergency operation of the stopping mechanisms of the 100DS should interruption of the signal occur. At the receiver end of the link an RF-operated relay, through interposing normally operated relays, provides a circuit or path for all functions to be performed as well as a path for engine ignition. Should the incoming signal be lost for some reason, the RF relay will become inoperative, breaking all function paths and at the same time operating automatically certain other relays which brake the vehicle to an emergency stop, shut off the engine, retard the throttle, move the transmission to neutral, and set the parking brakes. Through a time-delay system all power is turned off throughout the vehicle after all of these operations have been completed. This is to conserve battery power for subsequent restarting. This same shutdown system can be activated by the remote operator should an emergency arise that requires an immediate stopping action.

The RF link provided by the Kaar equipment controls vehicle or television functions by modulating them with Hammarlund tone signaling and decoding equipment. Tone signal generators, fully transistorized for low-power consumption, supply a tone of audio frequency for modulation of the carrier which is received at the vehicle by similar receiving equipment. A tone receiver or demodulator receives the incoming signal, removes that portion for which it is tuned, and sends this audio signal to a decoding point. At this point the signal is amplified and used to operate an interposing relay which in turn operates the relay which performs a certain function. It must

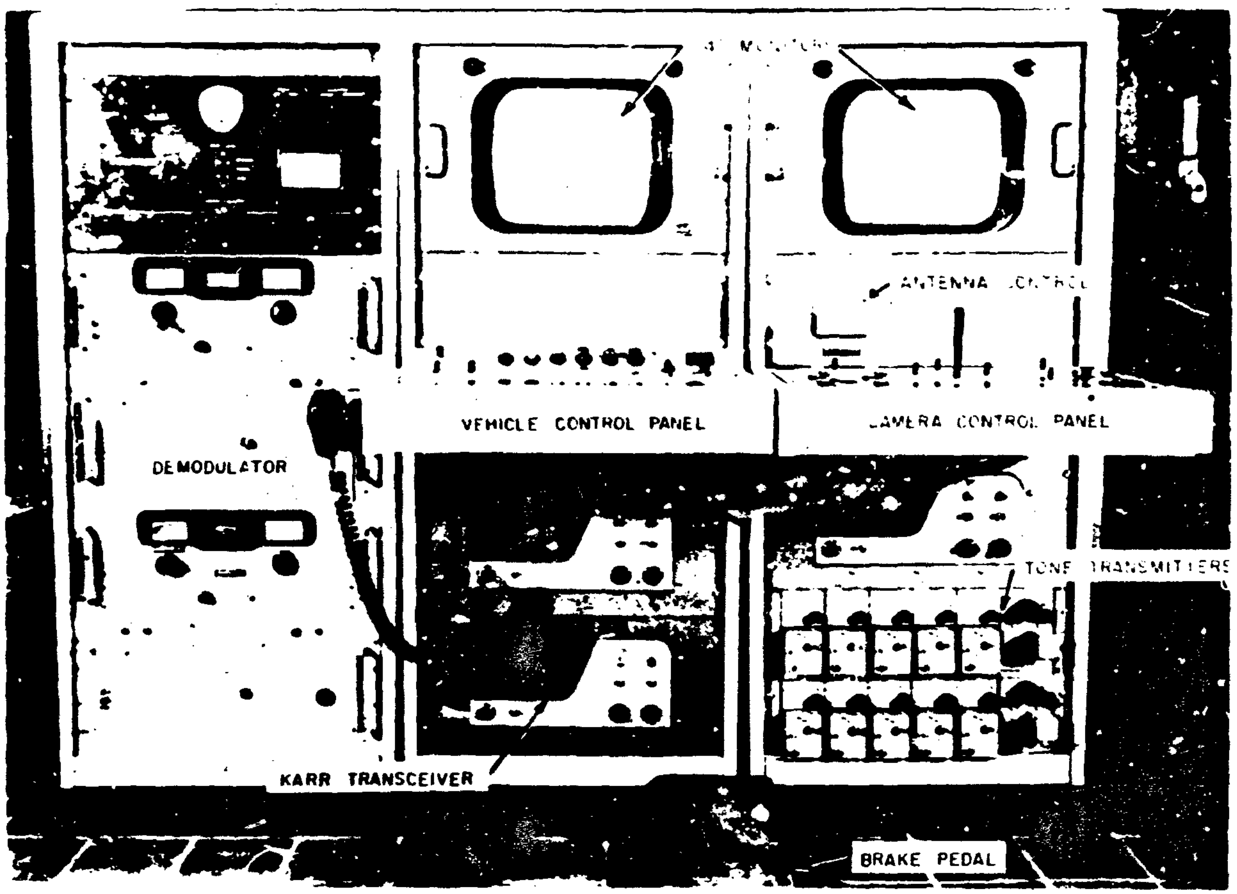


Figure 9. Control console for 700DS (front view).

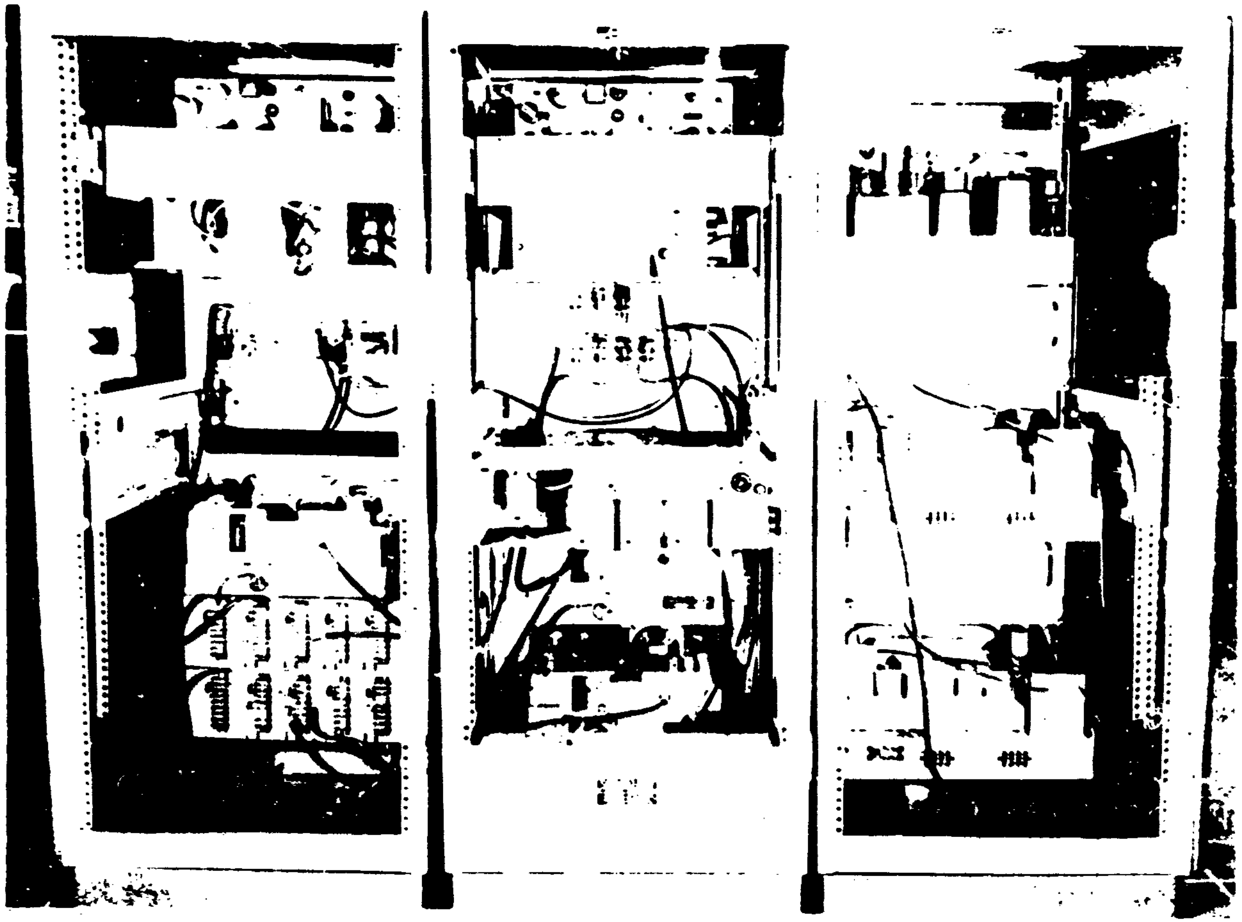


Figure 10. Control console for 100PS (back view).

be remembered that these demodulators are tuned for only one discrete frequency and will operate only if that particular tone is being received. One demodulator is required for each tone used: in the case of this application, 13 units — 5 for the vehicle control, 3 for the steering control, and 5 for the television control. The function relays are operated only if a certain series of these tones or a certain code is received. It is conceivable that a signal of proper frequency from some extraneous source could operate the decoding equipment. This could result in spurious information being received by the function relays, causing their operation at a most inopportune time. To prevent this, a coding system using sets of two to five tones is used. Therefore, for each function performance simultaneous reception of all the tones of the code assigned to that particular function must be effected at the decoding unit to provide the electronic path for its operation. The control system is very reliable, since reception of accidental or stray signals of proper frequencies and timing in such a manner as to cause a function to operate under this coding system is quite improbable. Figure 12 shows the coding system used for both the vehicle control and television control.

The same type of system is used for control of the television transmitting system. Full control is maintained over the cameras and transmitters from turning the power on by remote control to all movements of iris, focus, and range. A separate RF link is used for the television to permit greater versatility of equipment use during testing phases. One carrier could be used, since as many tones as desired can be used in the modulation. However, separation of vehicle and video control cannot be attained with one carrier, and at times there may be reason to operate one without the other for maintenance or test purposes.

Three individual RF links were provided for the complete remote control operation. Because of the remote control system employed, only one function at a time could be performed on each link. This system was employed for economy reasons during the feasibility study, although it is recognized that multiple-function selection in an operational-type vehicle is desirable.

One of the RF links controlled all of the functions of the vehicle with the exception of the steering. As in normal vehicle driving,

[illegible] Electronic equipment mounted on vehicle.

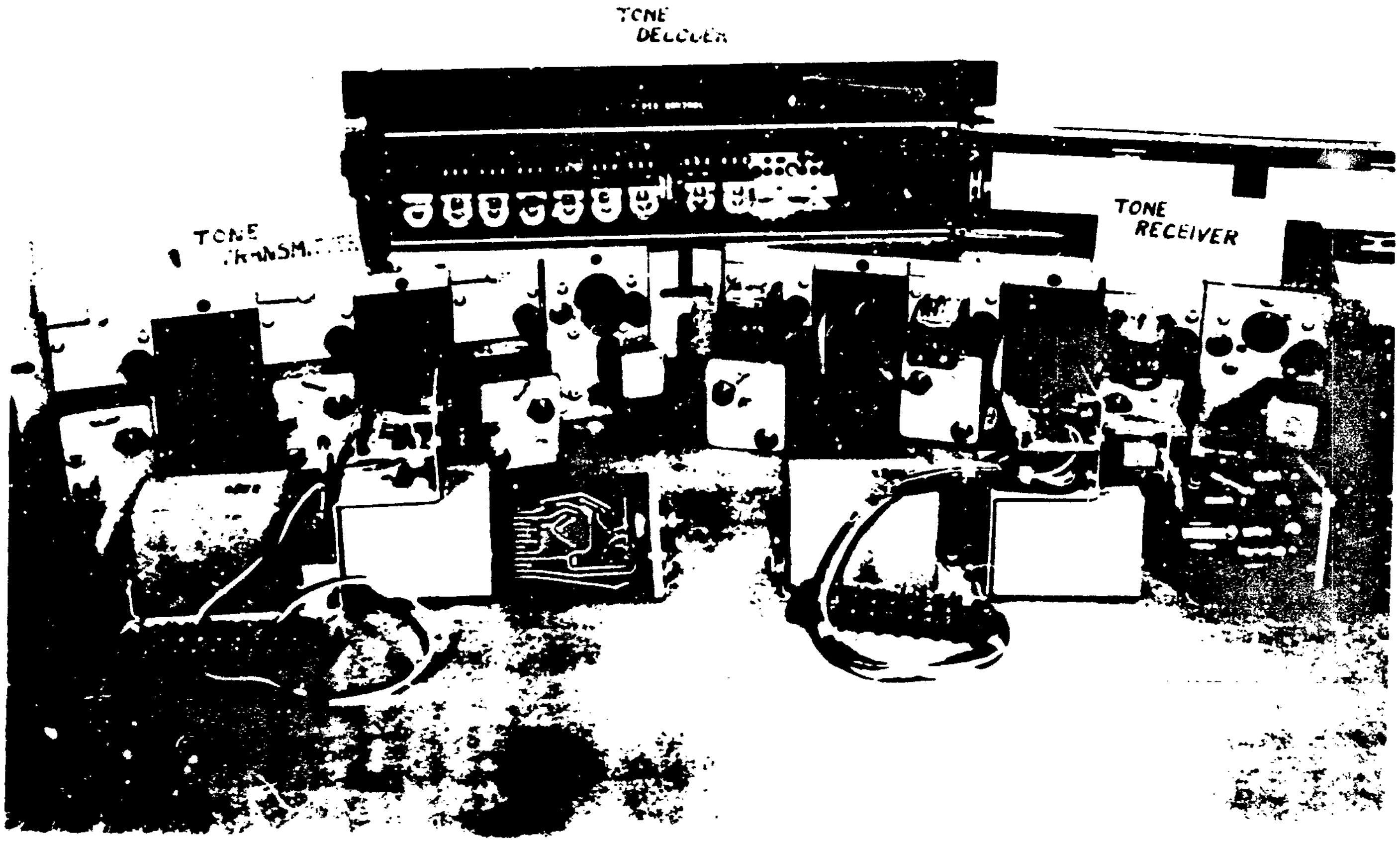


Figure 12. Tone equipment.

Figure 13. Transmitter equipment.

steering is a full-time control and is usually used in conjunction with other vehicle controls. Close simulation of normal procedures was desired and separation of the steering RF link from the vehicle link was considered mandatory.

The vehicle steering control mechanism was inadequate. Not only did the sweeper drift, but accurate, positive positioning could not be attained. This was the result of having only an off-on displacement-type movement. When the signal was in the "on" position, steering mechanism displacement continued until such time as the signal was discontinued. There was no visual contact with the vehicle itself; therefore the amount of movement could not be observed. It was very easy to overcontrol the vehicle because of transmission time-delay. The operator could not anticipate the vehicle movements from his viewing screen rapidly enough to prevent overcontrol.

The most probable solution to this problem is the installation of a proportional-type steering system, where a discrete movement of the control at the operator's console would result in a correspondingly proportional movement of the steering mechanism on the vehicle. This system would provide the same type of control as used in manual operation.

The video installation on the vehicle consists of three Dage 70-AR cameras, one in a fixed location on the front of the sweeper, one in a fixed location on the rear, and one in a pan-and-tilt unit in approximately the same position that a driver would occupy. All are inclosed in weather-proof, temperature-controlled housings. The 70-AR cameras were chosen for their fairly rugged construction and low cost, as compared to extremely rugged cameras of much higher cost. These cameras, for the purpose of feasibility testing, provided adequate results.

The pan-and-tilt unit was specially constructed to provide a full 360° of azimuth movement and 110° of elevation, from 55° below to 55° above horizontal.

Lenses on the front and rear cameras are interchangeable, both the 1-inch and ½-inch lenses having been used to

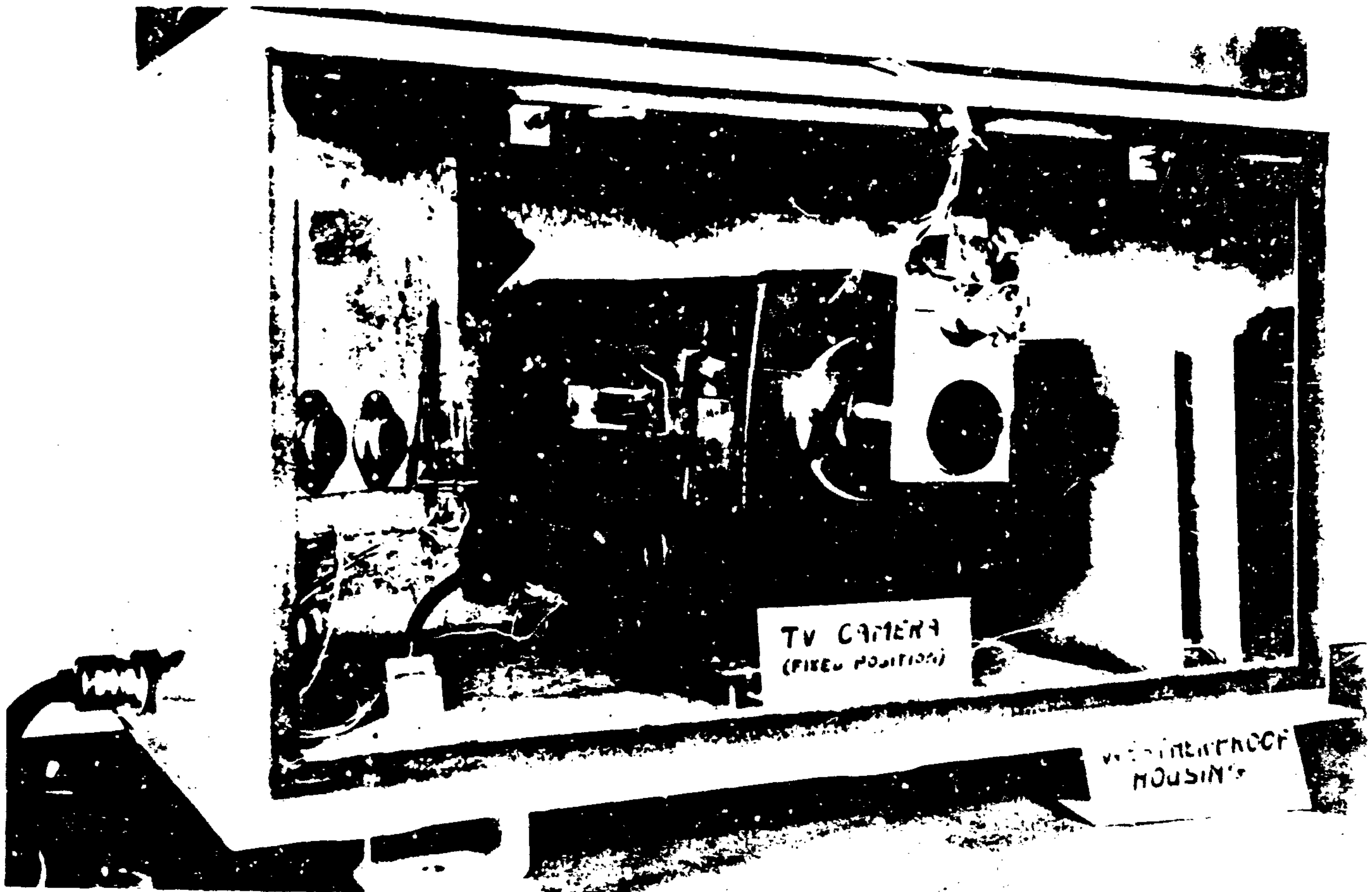


Figure 14. Fixed camera - type mounted on front and rear of vehicle.

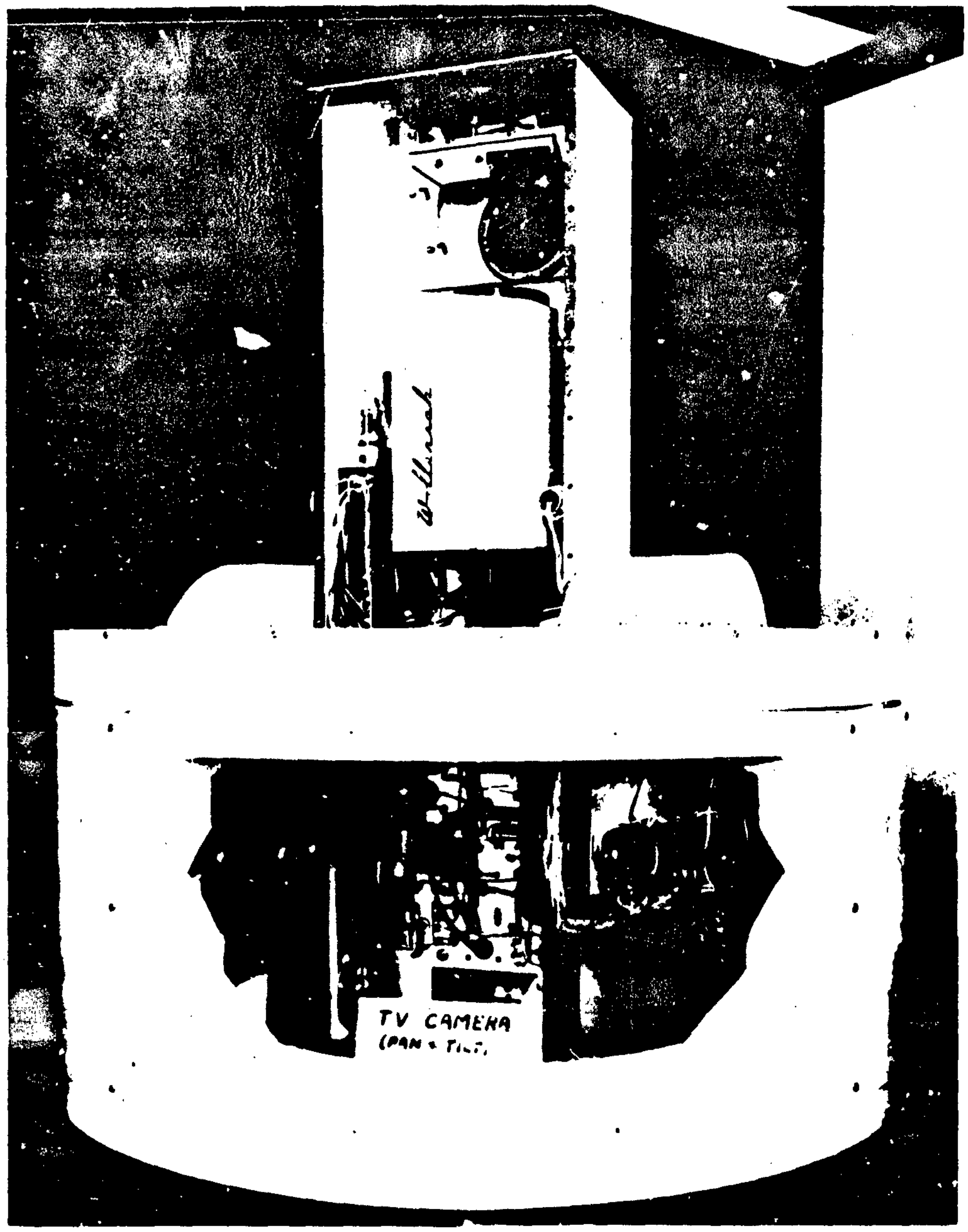


Figure 5. Pan and tilt camera mounted over driver's position.

determine desirable fields of view, and effects of image size with lens use. The top camera (pan and tilt) is equipped with a Wollensak Zoomar lens, which can be controlled remotely by the operator. The fixed cameras are primarily designed for use in work areas and the top camera for traveling.

The signal from the cameras is fed into two modified ARN-28 transmitters, the fixed cameras into one transmitter, the top camera into the other. The fixed cameras can be selected, either front or rear, by remote control by the operator. Operating frequencies of the transmitters are standard television frequencies, channels 15 and 17, UHF.

At the control position, the signal is received in Nems-Clarke receivers, sent to a Jerrold Tele-Trol demodulator, where it is then transferred to a Dage 14-inch video monitor. The picture presented to the operator is that as seen by the vehicle.

During the test runs a safety observer was on the vehicle to provide guidance where necessary while the remote operator gained experience and training. A voice link was maintained between the vehicle and control center for this purpose. The remote operator has full control of the vehicle, duplicating every function and operation that the driver can control.

The electronic system, as used in this particular application, had the requirement for several types of power supply. Although these requirements were not of an extraordinary type, they did pose problems in the vehicle system. The more critical limitations were found in the transmitting equipment employed. It is realized that a simplification of the electrical system is desirable and possible at the present time; however, at the inception of the remote study, the desired equipment was not available. Rather than delay the project for an indeterminate period, procurement was made on the available items, and proper power supplies provided. Certain problems were encountered by the use of these various power sources, but were adequately controlled so that the study could be completed without the delay that would have been introduced by waiting for other electronic equipment. Since this was a prototype configuration, it is believed that the detriments of the less desirable equipment were justified in the interests of the required fallout decontamination study.

The equipment on the remote operator's console used primarily 110-120-volt, 60-cycle power. Some of the tone equipment and the control panel relays required 24-volt, direct current.

Common alternating current power sources were adequate for the primary power. This could be supplied by any normal power output, either commercial or by portable generator.

The 24-volt, d. c. supply was provided by a standard rectifier supply, mounted in the rear of the control console. This unit can be seen in figure 10, center section, at the bottom of the rack. The 110-volt a. c. power supplied to the console was converted into the required d. c. supply. Thus only one external power source was required.

The equipment was of such a type that strict regulation was not necessary. Normal fluctuations could be handled by the regulatory networks of the operating equipment.

The greatest problem in power supply was involved in the vehicle requirements. A number of sources were needed for the various equipments utilized. These sources included 110-120-volts a. c., 24-volts d. c., minus 150-volts d. c., plus 300-volts d. c., 1,000 volts d. c. The only power source available on the vehicle in addition to the generator/battery system was a 150-ampere output, 24-volt d. c. generator driven by the auxiliary engine. This supply proved barely adequate for the demand imposed upon it; however, by the greater use of transistorized electronics in any future considerations, the power requirements could be substantially decreased.

The generator, driven by the auxiliary engine, provided a very accurate and stable source of power, being regulated quite adequately by a carbon pile regulator. The only fluctuation of any consequence arose when the sweeping brushes, blower, and vacuum systems were engaged. At this time, the increased drag on the engine induced a momentary slowing of the engine with a resultant decrease of generator RPM. However, this fluctuation was effected for only a very short time, and the decrease in voltage amounted to less than ½ volt. The result of this fluctuation on the electronic equipment was insignificant.

The d.c. power, as provided by the generator, was used directly by the remote control relays and devices associated with the video transmitting system. All the relays governing the operation of the vehicle itself were provided power from the vehicle batteries. The vehicle had a 24-volt system installed, meeting military specifications. In addition, the vehicle batteries provided the power for the one converter, which supplied the a.c. required by the radio tone equipment providing the link for remote operations.

Two a.c. converters were installed on the vehicle, one to provide power for the remote control link with the operator, the other provided power for the video transmitting equipment. The one converter, as stated operated from the vehicle battery supply, the other derived its source from the d.c. generator, operating at all times the generator was operating. The capability of on-off control for the battery-operated converter existed. Two converters were primarily used because of space limitations; one large converter would have sufficed, but finding a place for its installation was difficult. Later, this dual installation proved helpful in the solution of a problem that arose. The transmitters required a very "clean" source of power, which required filtering the a.c. provided to them to assure a clear transmission. It was much easier to apply this filtering process to the smaller converters than to the cumbersome large one.

The other power packs providing the 1,000 volts, 300 volts, and 150 volts were supplied directly by the 24 volts from the d.c. generator.

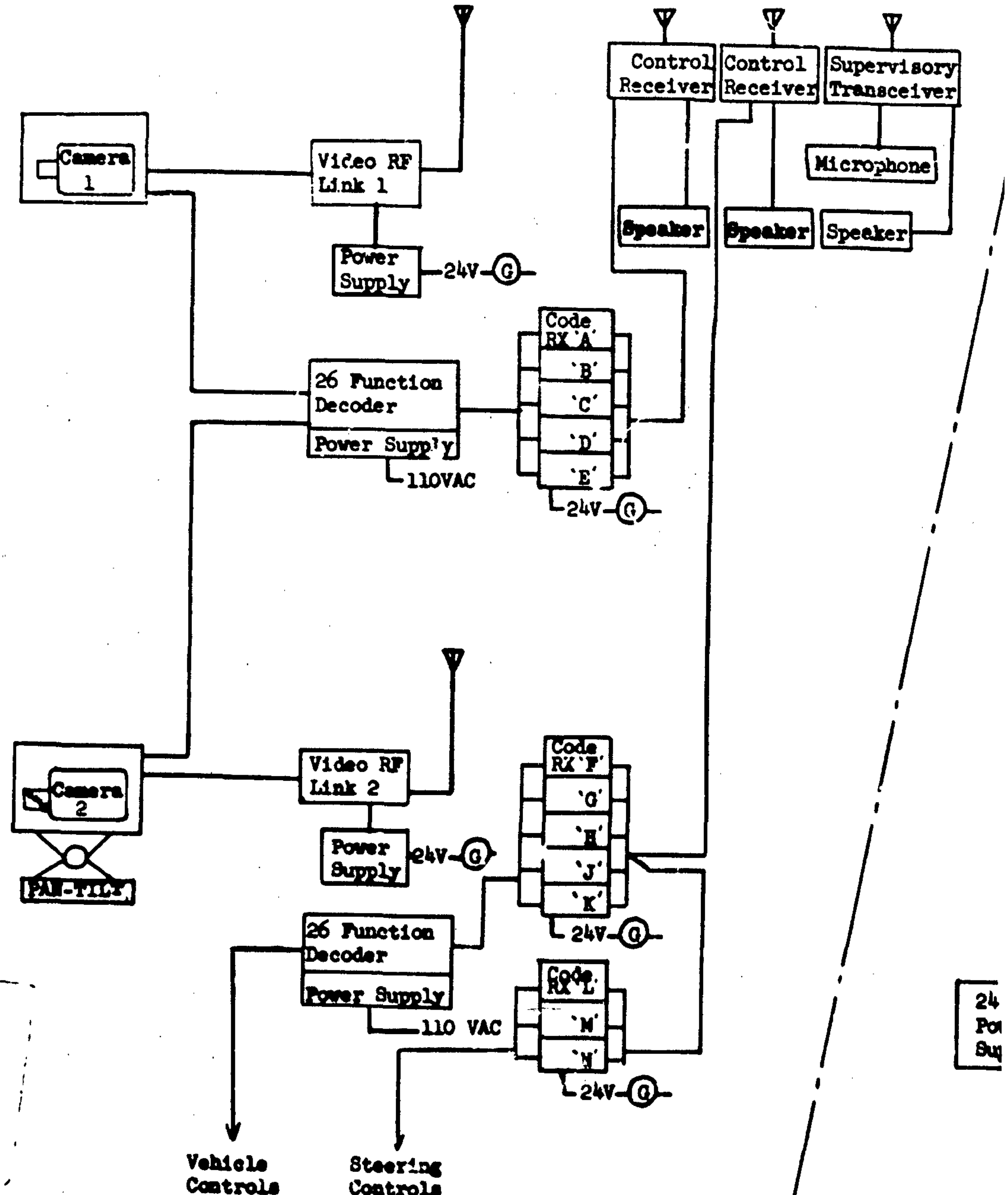
Figure 16 shows a block diagram of the complete installation on both the operator's console and the vehicle.

C. Experimental procedure for 100DS tests.

1. Production and dispersal of fallout simulant.

For these six tests, an area 32 feet by 102 feet was contaminated with a simulated fallout material using Lanthanum-140 as the radioactive tracer. The preparation of the synthetic fallout is described in detail in an NRDL report entitled The Production, Dispersal, and Measurement of Synthetic Fallout Material, Vol I, USNRDL, by Sartor and Lane.

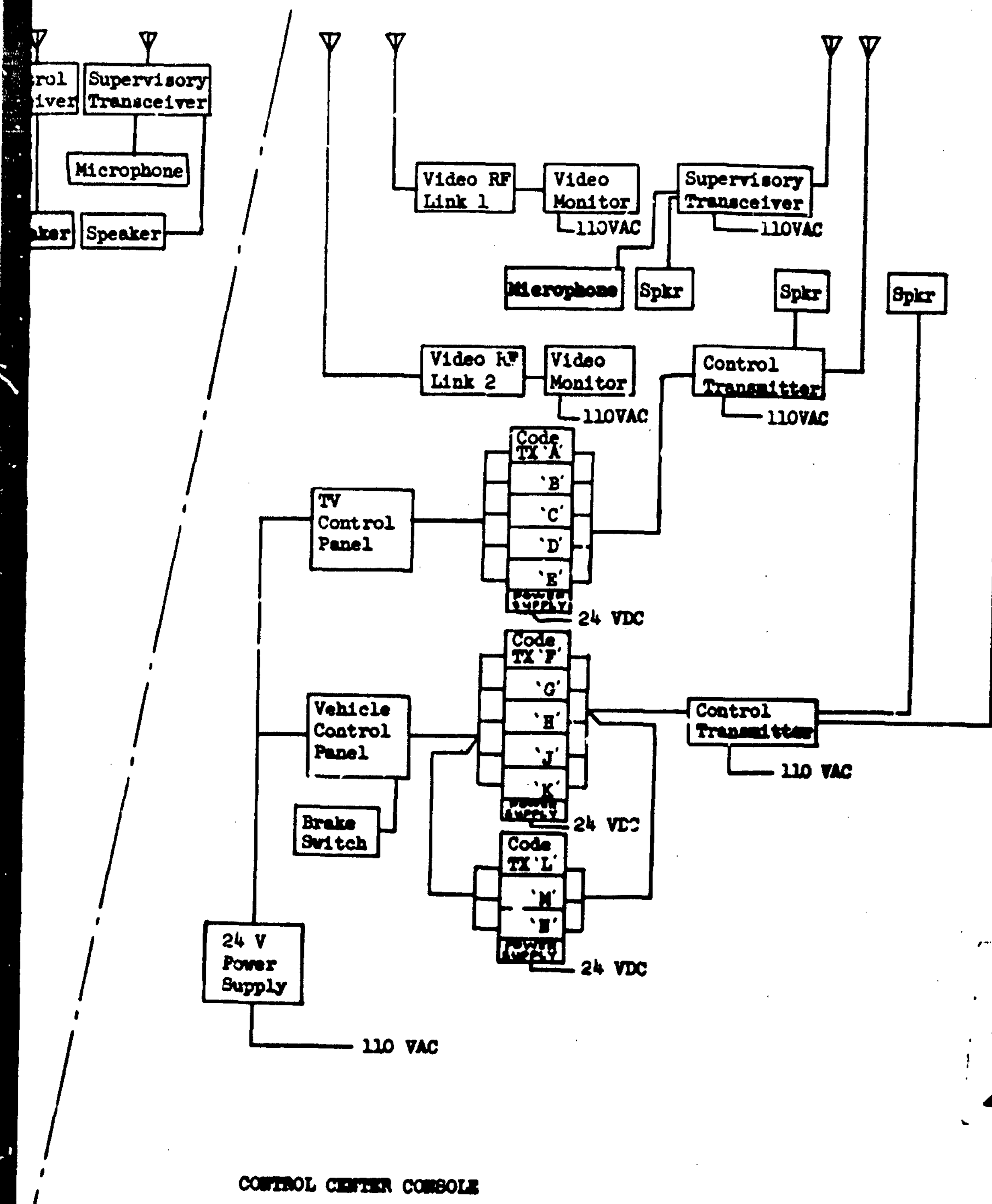
For these specific tests, the mixture of sand and lanthanum was made in two different batches. The mixture used for each test is indicated



REMOTE VEHICLE

-(G)- 24 VDC Engine Driven Generator

Figure 16. Block diagram -



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6. Block diagram - remote system.

in table 4. This table also lists the concentration of contaminant used for the tests. The amount to be spread on the test pad was determined by the NRDL fallout model. According to this model, 10 grams per square foot, 33 grams per square foot, and 100 grams per square foot will simulate radiation levels of 300 r per hour, 1,000 r per hour, and 3,000 r per hour respectively at 1 hour after burst from a high-yield (MT) land-surface burst.

"The dry synthetic fallout material was dispersed over the test pad from a modified Burch Hydron Spreader mounted on the rear of a 2½ cubic yard dump truck. An aluminum hopper was installed on the truck to contain the synthetic fallout material and feed it directly into the spreader when the truck bed was raised."[8]

2. Measurement of synthetic fallout.

To determine the actual quantity of material dispersed, 12 sampling pans were placed on the test pad (at the positions indicated in figure 17), before the fallout was spread. Immediately after the dispenser had passed over these pans, each was collected and placed in a plastic bag. All 12 pan samples were then intermixed and three 10-gram samples of the mixture taken to determine the specific activity in the 4 π ion chamber. These data appear in tables 12 and 13 of appendix A.

3. Data collection.

To determine the decontamination efficiency of the vehicle, measurements were made of the radiation level present on the test pad prior to contamination (background), after contamination (initial), and after decontamination (final). The measurements were recorded in counts per minute by use of a shielded gamma scintillation detector unit. The detecting unit of the instrument consisted of a 1-inch NaI scintillation crystal on a photomultiplier tube. The detecting unit was inclosed in a lead pig with approximately 4-inch thick walls. The pig had a collimated aperture whose geometry permitted a 3-foot-radius circle on the contaminated plane to contribute approximately 95 percent of the instrument response. The data as recorded appear in appendix A.

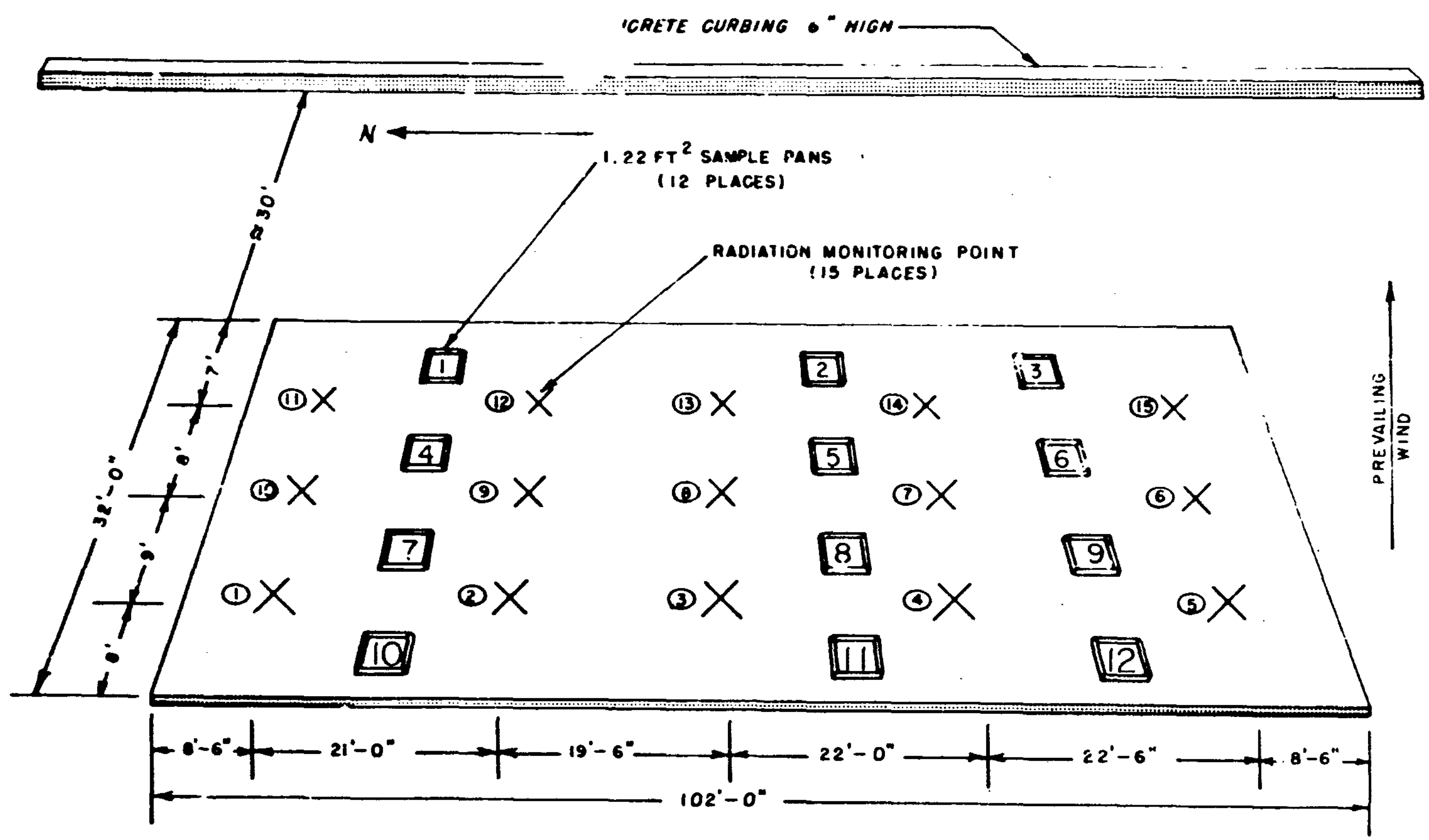

Figure 17. Asphalt test pad

Table 4

TYPE, AMOUNT AND STRENGTH OF SIMULATED FALLOUT

Test	Bulk Carrier Material	Isotope	Amount (gm/ft^2)	Strength (uc/gm)	Strength ($\mu c/ft^2$)	Total (curies)
Remote #1	Same for	La-140	26.6	20.6	548	1.8
Remote #2	all six	La-140	57.0	9.5	542	1.8
Remote #3	tests.	La-140	50.6	6.3	319	1.0
Manual #1	See insert.	La-140	22.6	8.4	190	0.62
Manual #2		La-140	40.6	6.1	248	0.81
Manual #3		La-140	38.4	5.9	227	0.74

BULK CARRIER MATERIAL

Microns	Mesh	Per cent by Weight
295-246	50- 60	58.[illegible]
246-208	60- 70	[illegible].3
208-177	70- 80	10.5
177-147	80-100	3.2

IV. RESULTS.

A summary of the results of the testing of the sweeper under remote control operation and manual control operation appears in table 5. All six tests were conducted on the same asphalt test pad (see figure 17).

The decontamination efficiency of the vehicle is defined as the percentage of the contaminant that the vehicle picked up and retained. Mathematically, this percentage value is represented by the following:

$$\% \text{ efficiency} = \frac{I_C - F_C}{I_C} \times 100$$

I_C = corrected initial reading (after contamination)

F_C = corrected final reading (after decontamination)

The time used to decontaminate the test pad was recorded as both the total time for the entire operation and the actual decontamination time. The

total time included the time used to turn the vehicle around and reorient it with the test pad. The test pad was located in the center of a large paved area.

The number of passes made over the test pad were counted by an observer in the test area. They represent the actual number of times that the sweeper passed over the test pad with the sweeping mechanism of the vehicle in operation. These patterns are shown in figures 19, 21, 23, and 25. A photograph of the test area, the vehicle, and the contaminant appears in figure 28.

A. Discussion of tests.

1. Remote Test #1.

One hour prior to test time, the 1,000-volt power supply burned out two transistors, and as a result, the pan-and-tilt camera was inoperative. The test was conducted anyway and the results are based on operating the sweeper with only the front-mounted stationary camera in use. The stationary rear camera was not used for any of the tests. The front camera was tilted

Table 5

SUMMARY OF RESULTS OF DECONTAMINATION TESTS ON 100DS SWEEPER

Test Number	Date and Time of Test	Decontamination Efficiency (%)	Time Used to Decontaminate (minutes) ***		Number of Sweeping Passes Made on Pad
Remote #1	14 June 0955	99.5	*37	** —	9
Remote #2	16 June 1000	99.8	15	—	11
Remote #3	17 June 0825	99.9	14	4.3	9
Manual #1	21 June 0825	99.5	2.3	1.0	7
Manual #2	22 June 0830	99.8	2.5	52 sec	7
Manual #3	22 June 1120	99.8	2.5	52 sec	7

* Time used in entire operation
**Time used in actually sweeping the pad
***Vehicle operated at 4 miles per hour for remote tests and 9.5 miles per hour for manual tests.

downward at such an angle that the ground from directly in front of the vehicle out to 20 feet in front of the vehicle could not be seen. Without the use of this pan-and-tilt camera, this limited line of sight greatly hampered the control operator.

Some difficulty was experienced with one of the two TV monitors at the control console. At times, the picture seemed to vibrate up and down. This did not appear to be due to the vibration of the camera on the vehicle. This was apparent at all times; however, the picture ranged from fair to very poor.

As can be seen in figure 19, the vehicle sometimes drifted from left to right and sometimes from right to left. This was due to the sensitivity of the remote control steering mechanism and some inherent faults of the vehicle. To try to correct this drifting while decontaminating was nearly impossible. The drifting was not noticeable for a short time because of the limited line of sight of the front camera. By the time it was noticed by the control operator, it was too late to make a steering correction before that particular pass over the pad was completed.

In some cases the vehicle drift became apparent in time to permit a change in direction. However, the correction was usually ineffective because of the sensitivity of the steering mechanism. An attempt by the operator to compensate for the error would result in a new drift in the opposite direction. A decrease in the steering sensitivity would have permitted a more accurate directional control and a more stable course line.

Maintaining a constant vehicle speed or engine rpm was quite a problem. There was no indicator at the control console showing the throttle setting, engine rpm, or vehicle speed. If the engine rpm had been set for a reasonable decontamination speed, it would have been too fast for turning the vehicle around at the end of each sweeping pass. If the rpm had been set for a safe turning speed, it would have been too slow for desirable operational decontamination. There was no way of changing from one rpm to another and knowing exactly what the new rpm was; therefore the remote operator had to use his own judgment during the operation. He swept as fast as he thought safe and then slowed down to turn the vehicle around; again advancing the

throttle when the vehicle was alined with the pad for another pass. There is no way of knowing the exact speed used for these tests but it was approximately 1,700 rpm. In first gear, 1,700 rpm is approximately 4 mph.

The auxiliary engine which operates the sweeping brushes on the vehicle had a tendency to overheat quite badly. As a result, it was necessary to disengage the brushes at the end of each sweeping pass over the test pad. Every time the brushes were disengaged, a small but noticeable amount of contaminant was deposited on the ground. It was not possible at the time of the test to determine if this was contaminant falling from the hopper, trailing from the edge of the brushes, or being pushed in front of the brushes. This contaminant, deposited near the area of the test pad, could have given a false indication of the count rate had it been closer to the test pad than it was.

Figure 18 presents a pictorial analysis of the data from Remote Test #1. The corrected counts per minute appear at each of the 15 stations where they were recorded. Also, an indication of the effect of the wind is shown. A clear indication of the wind effect is seen when one notices that the highest final counts were recorded at Stations 11, 12, 13, and 14. This was due to the contaminant that was blown from upwind and stayed on the downwind stations, as well as to that which was blown off the test pad and collected on the east side of the pad After the pad was decontaminated, the only contaminant remaining in the test area was that which was blown to the east (downwind) and deposited near the test pad. This contaminant contributed to the high count rate recorded on the east edge of the pad (Stations 11 through 14).

The contaminant dropped by the sweeper on the north and south edges of the test pad when the brushes were disengaged had little or no effect because of the distance from the test pad. This contaminant was no closer than 15 feet to the pad. The detecting unit of the gamma detector had a collimated aperture whose geometry permitted only a 3-foot-radius circle on the pad to be counted.

It was not realized at the time of the test that the windblown contaminant would affect the test data. It can be seen now, however, that it did have a slight effect. This can be seen from figure 18. The count rates at stations

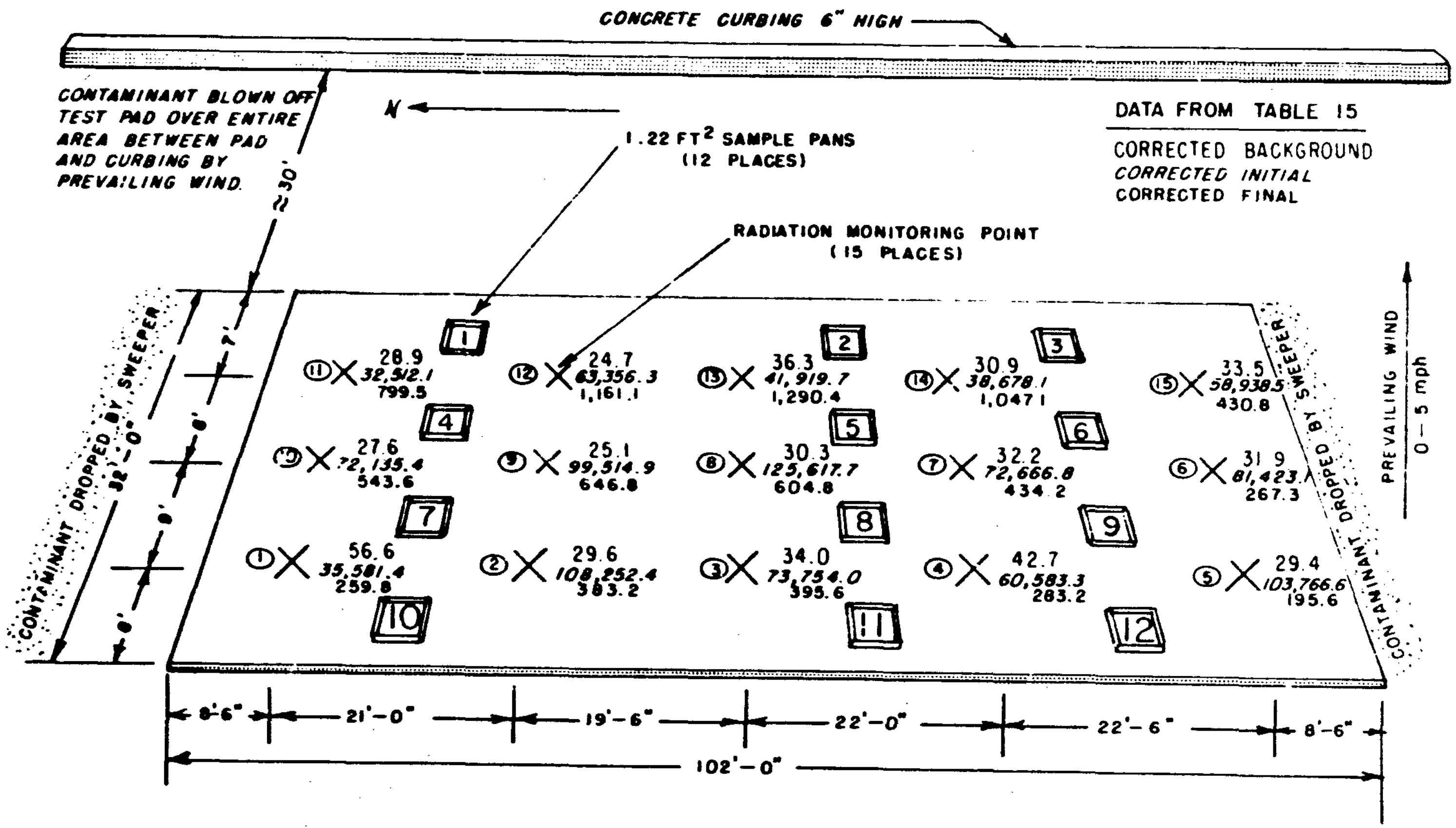

Figure 18. Asphalt test pad and corrected data for remote test #1.

11 through 14 are higher than the count rates at the other stations. Stations 11 through 14 are downwind. The detector was probably recording the count rate from the contaminant that was blown from upwind and deposited on these downwind stations. Also, the detector could have been recording some of the scattered radiation emanating from the contaminant deposited by the wind on the adjoining downwind area. The slight change did not alter the pickup efficiency at all. If the data from stations 1 through 15 are used, the efficiency becomes 99.5 percent, and if only the data from stations 1 through 10 are used, the efficiency is still 99.5 percent.

Figure 19 is a layout of the pattern which the vehicle traced while decontaminating the test pad. This layout was drawn by an eyewitness in the test area. It is only a representation of how the vehicle appeared to move across the test pad. The purpose of this layout was to make available to the operator a study guide to help him reduce his driving time as well as increase his cleaning efficiency in future tests. It also presents a means for understanding why the final count rate varied from station to station. This is demonstrated by comparing the locations of the stations where readings were recorded with the pattern, indicating how many times that station was swept. There was no other means available except visual recording for establishing the paths the vehicle followed.

2. Remote Test #2.

At the conclusion of Remote Test #1 at 1515 hours (mean time) on 14 June, the count rate on the test pad, corrected for background, was 565.4 cpm. (Before background correction it was 598.6 cpm. Since there was nothing in the area to change the background, it can be seen that the 565.4 cpm were from the contaminant that was left on the ground after decontamination. This contaminant was composed of La-140 and decayed with a half-life of 40.2 hours.

From 1515 hours on 14 June until 0845 hours on 15 June, when background was again taken, the La-140 would have decayed for 17.5 hours. If the 565.4 cpm recorded on 14 June were from La-140, it would have read 418.4 cpm at 0845 hours on 15 June when the background was taken. The corrected background on 15 June was 296 cpm rather than 418.4 cpm as it should have

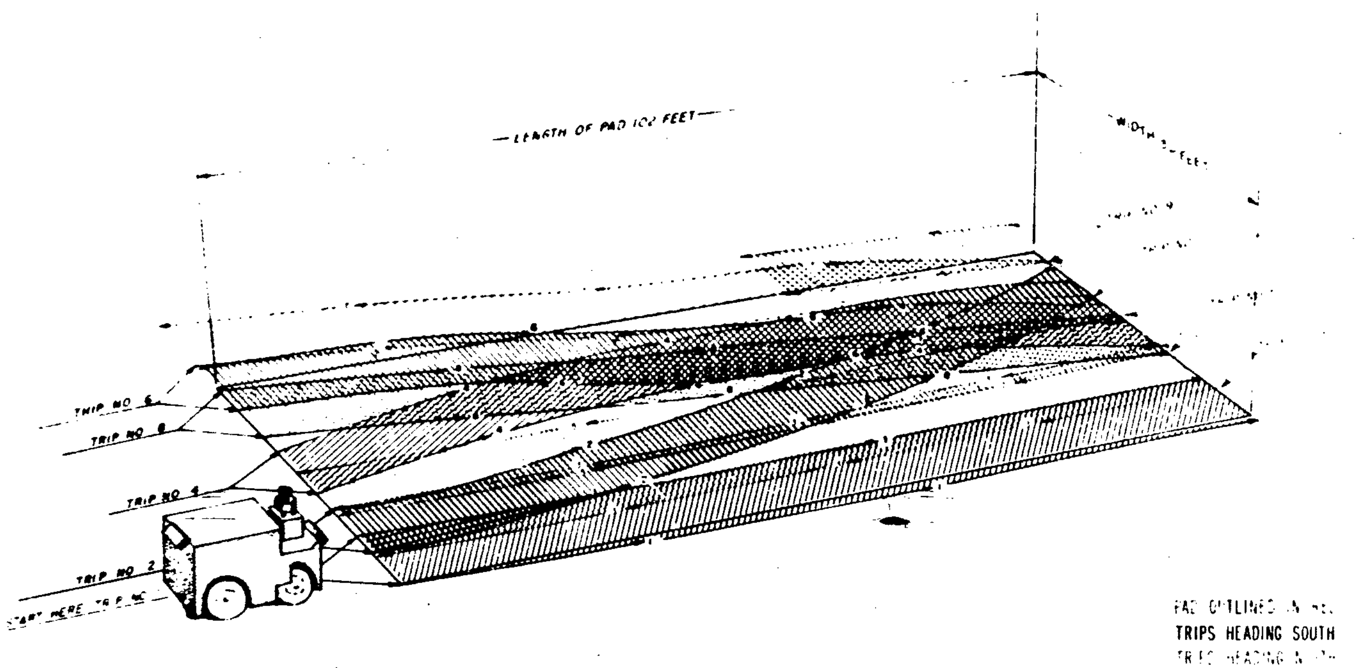

FIGURE 19. SWEEPING PATTERN FOR REMOTE TEST NUMBER 1.

been. The explanation for this is that the wind blew some of the contaminant onto the downwind stations and some of it off the pad overnight. This is evident from the data as the count rate on the downwind side of the pad was about twice that on the upwind, indicating that the wind had blown the contaminant.

The count rates on the downwind stations after Remote Test #1 were higher than on the upwind stations, so it is logical that the downwind stations would read higher the next day. The difference in count rate is accounted for by the contaminant blown downwind.

The pad was contaminated on 15 June for what was to have been Remote Test #2; however, the test was cancelled because of mechanical difficulties and the wind. After this test was cancelled, the pad was decontaminated with the sweeper and the downwind areas swept with a broom. The pad was sufficiently cleaned so that any remaining contaminant should have been insignificant the next morning. The downwind area was also cleaned so that any contaminant remaining on it should have been too small and too far away to affect the count rate on the pad.

When background data were collected prior to the rescheduled Remote Test #2 on 16 June, the count rate averaged 296 cpm. This high count rate could not have been all from true background. There is no reason to believe that the true background increased from approximately 33 cpm on 14 June to 296 cpm on 16 June. The only cause for this large increase was residual contaminant either on the pad or on the downwind area or both. If it is assumed that the true background remained constant from 14 June to 16 June and that the increase was due to La-140 in the test area, then the background due to the La-140 was 265 cpm. If it decayed from 1025 hours (background mean time) to 1400 hours (final mean time) it would have been 249 cpm at the end of the test. If the true background is then added to this, the average corrected background at the end of Remote Test #2 would be 282 cpm. The average final count rate after decontamination was 51 cpm.

As can be seen from figure 20, the final count rate was less than background at several stations. These stations were located upwind. There was a 15-20 mph wind during the test and this blew some of the contaminant from the upwind stations to the downwind stations. In this case, one would expect the downwind stations to indicate the largest readings. This was the case as can be seen by the data at stations 11 through 15, the downwind stations. Of

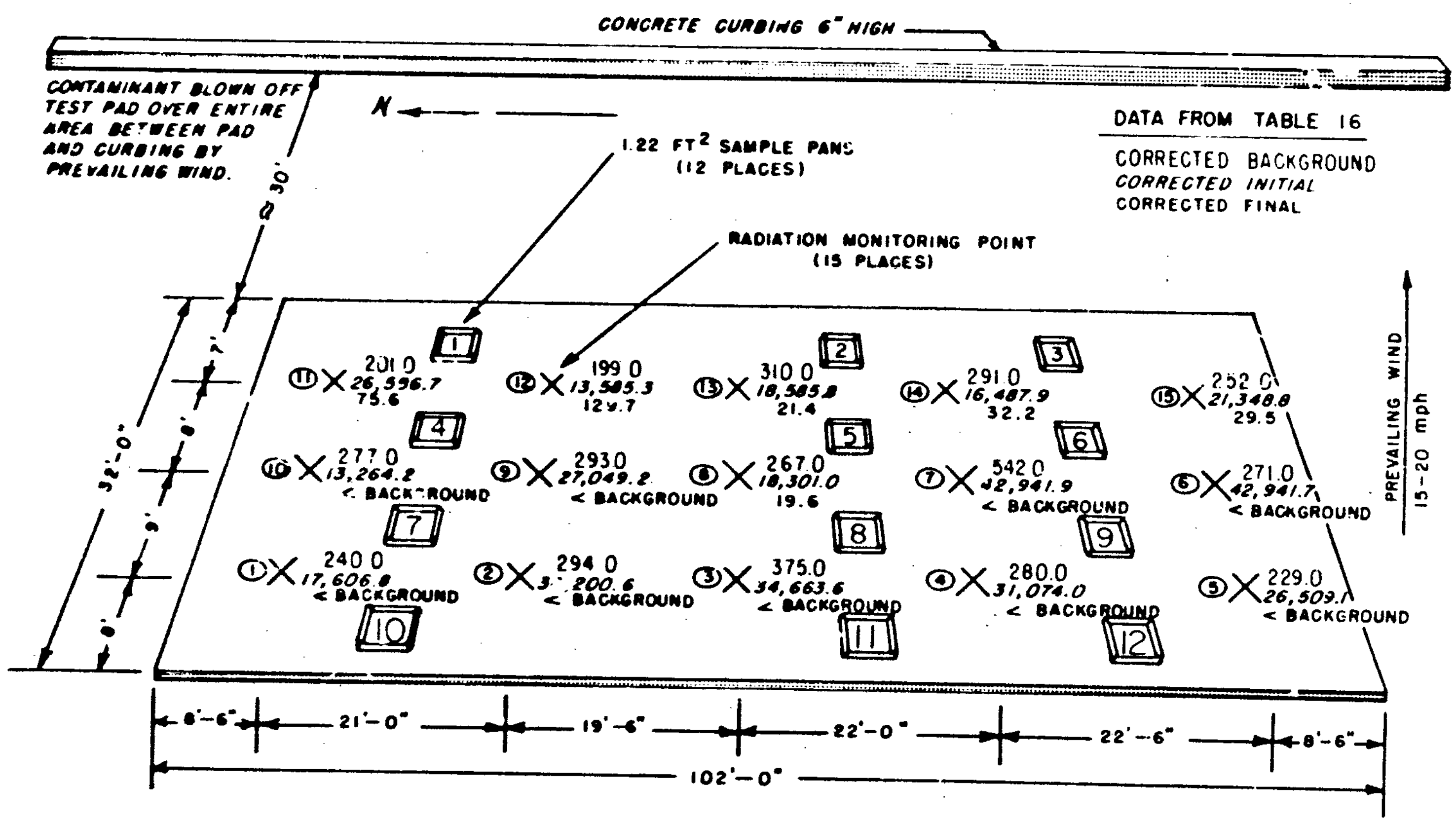

Figure 20. Asphalt test pad and corrected data for remote test #2.

course, all the contaminant from upwind did not stay on the pad. Some of it blew onto the downwind area east of the pad. There is no way of knowing how much of it blew off and how much stayed on the pad.

After the pad had been remotely decontaminated with the sweeper, it was decided that the surrounding area should be decontaminated as well as the pad since the wind had scattered some contaminant. Some of the contaminant which had been measured as background both on the pad and surrounding area was removed in cleaning the area after the test.

Since the surrounding area was decontaminated with the sweeper, it was concluded that part of the contaminant that was on the downwind area adjoining the pad was removed before the final readings were recorded. This contaminant was present when background was taken but was gone when the final readings were taken. This explains in part why the average final count rate was less than background.

Figure 21 indicates that the entire test pad was decontaminated—most areas at least twice —so it can be assumed that the decontamination efficiency of this test would be limited only by the limits of the vehicle itself. The vehicle had demonstrated a decontamination efficiency of greater than 99 percent, therefore the results of Remote Test #2 are comparable with Remote Test #1 in regard to efficiency. If the data from the stations which read greater than background are used, the decontamination efficiency for Remote Test #2 becomes 99.8 percent. It took less than one-half the time to decontaminate the pad in Test #2-- 15 minutes compared to 37 minutes for Test #1. During this test a better system was developed for passing over the area and turning around after each pass. It should be pointed out that the console operator became more proficient with practice.

Figure 21 was sketched by an eyewitness stationed in the test area. Its system of coding is identical to that of figure 19.

It will be noted from table 4 that the strength (microcuries/gram) of contaminant for this test was less than one-half that for Remote Test #1. This was due to the fact that the same batch of contaminant was used for the second test as for the first. Because of the length of time between tests and the short half-life of lanthanum (40.2 hours), the strength was considerably reduced at

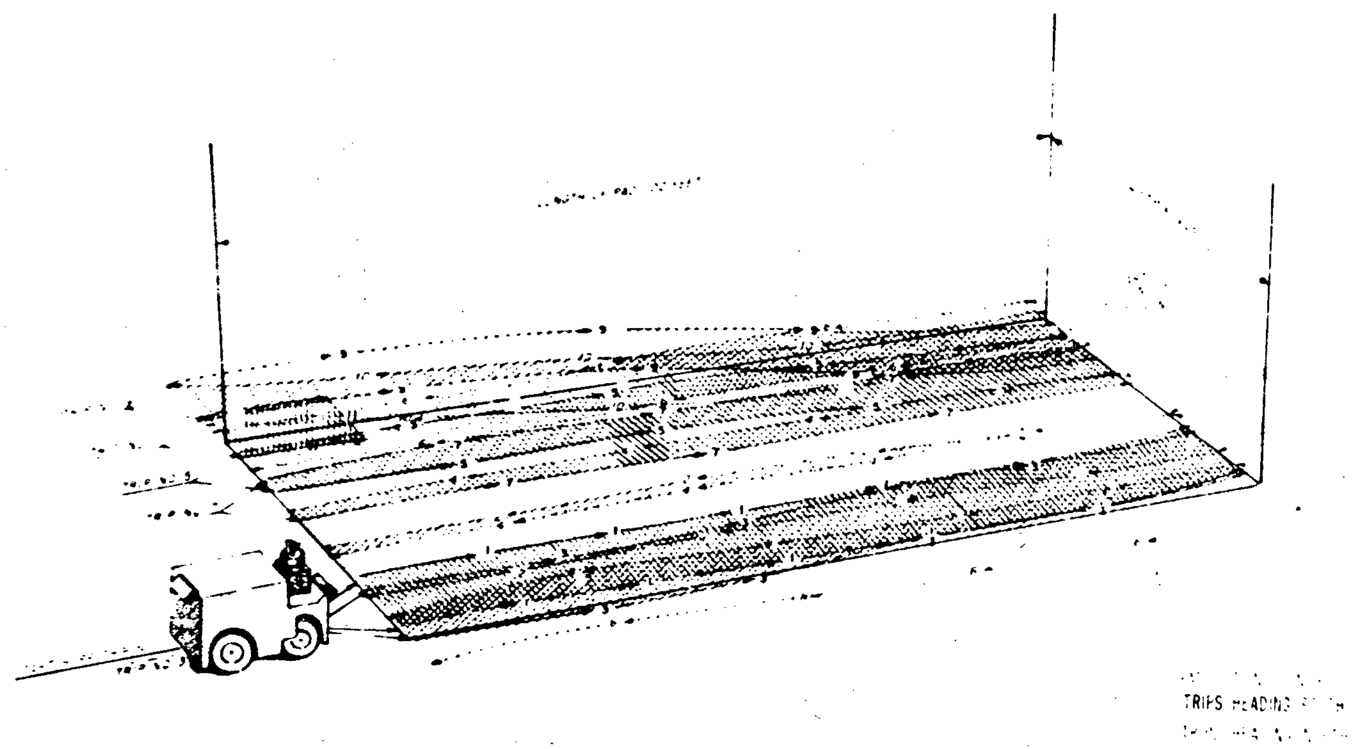

FIGURE 21. SWEEPING PATTERN FOR REMOTE TEST NUMBER 2.

the time of the second test. Because of this, the amount of contaminant spread was greater for this test. It was necessary to have a strong source for good counting statistics and this required about twice as much fallout per square foot for Test #2 as for Test #1 in order to have the strength (microcuries per square foot) approximately the same. The total strength in curies was also the same for both tests.

The only mechanical difficulty noted during this test was a vehicle hydraulic leak. The leak had been evident for some time but had not been isolated. It was not major enough to postpone testing for repair. The auxiliary engine continued to heat up in a short period of time. It was necessary once again to disengage the brushes after each pass to reduce the load on the engine and allow it to cool. As in the first test, with each brush disengagement, some contaminant was spilled. In this test, however, this contaminant was swept up from the surrounding area before the final readings were recorded, thus eliminating any possible effect on the count rate.

As in Remote Test #1, this test was conducted with only one camera in operation. The 1,000-volt power supply burned out transistors, causing the pan-and-tilt camera to be inoperative.

Some mechanical difficulties were noted on the day of the "cancelled" Remote Test #2. Just before the test was started, the picture on the monitor screen went blank. It was obvious from the lines on the monitor screen that the camera was still transmitting, but there was not a visible picture. It was determined that the lens on the camera had vibrated off. This had happened previously. The design of the lens system was very poor. The lens actually supports a cantilevered motor which remotely changes the iris. This weight, combined with the vibration of the vehicle, caused the three small set screws which support all this weight to grind their way through the lens clamp, thus releasing the means of support for the lens.

3. Remote Test #3.

Once again, because of the short half-life of the contaminant, it was necessary to put down twice as much contaminant as was spread for Remote Test #1. The pad was covered with a density of 50.6 grams or 319 microcuries per square foot. A total of 1.0 curie was placed on the pad. A comparison of these values with those for the other tests appears in table 4.

Before the test pad was contaminated, the average corrected background was approximately 178 cpm. Again, it is seen that this is composed partly of true background and partly of residual lanthanum. If it is assumed that the true background remained constant from 14 June and that the residual contaminant was from the preceding test, then the background is changing as the test progresses.

The total count rate at the end of Remote Test #2 was 259 cpm. If the average true background of 33 cpm is subtracted, the remaining 226 cpm are a result of the residual contaminant. If this residue is decayed for 18.8 hours (from 1400 hours on 16 June to 0850 hours on 17 June), it becomes 164 cpm. When the true background is added to this, the corrected background from the preceding day will be 197 cpm. The actual corrected background recorded prior to the test was 178 cpm. If these two readings are corrected for the difference in radium standards, they will agree.

As can be seen from figure 22, the final count rates at all of the stations except one is less than background. This can only be accounted for by assuming that the sweeper picked up some of the residual contaminant from the preceding test.

If only the one value that is greater than background is used for the calculation, the efficiency of the sweeper for Remote Test #3 becomes 99.9 percent.

Figure 23 indicates that the entire pad was decontaminated—some areas twice. On the seventh pass, about a 6-foot strip off the pad and on the downwind adjoining area was decontaminated. This helped reduce the possible effect of the contaminant on the results.

This test lasted 14 minutes, which was an improvement over the two previous tests. Only nine passes were required to complete the decontamination of the pad. This was also an improvement over the two previous tests.

Part of the time consumed in a test is used for turning the vehicle around and alining it with the pad. A time check was made to determine the actual time that the sweeper was on the pad. This was approximately 4.3 minutes.

This test was conducted with only one camera in use. The picture on the monitor was very good.

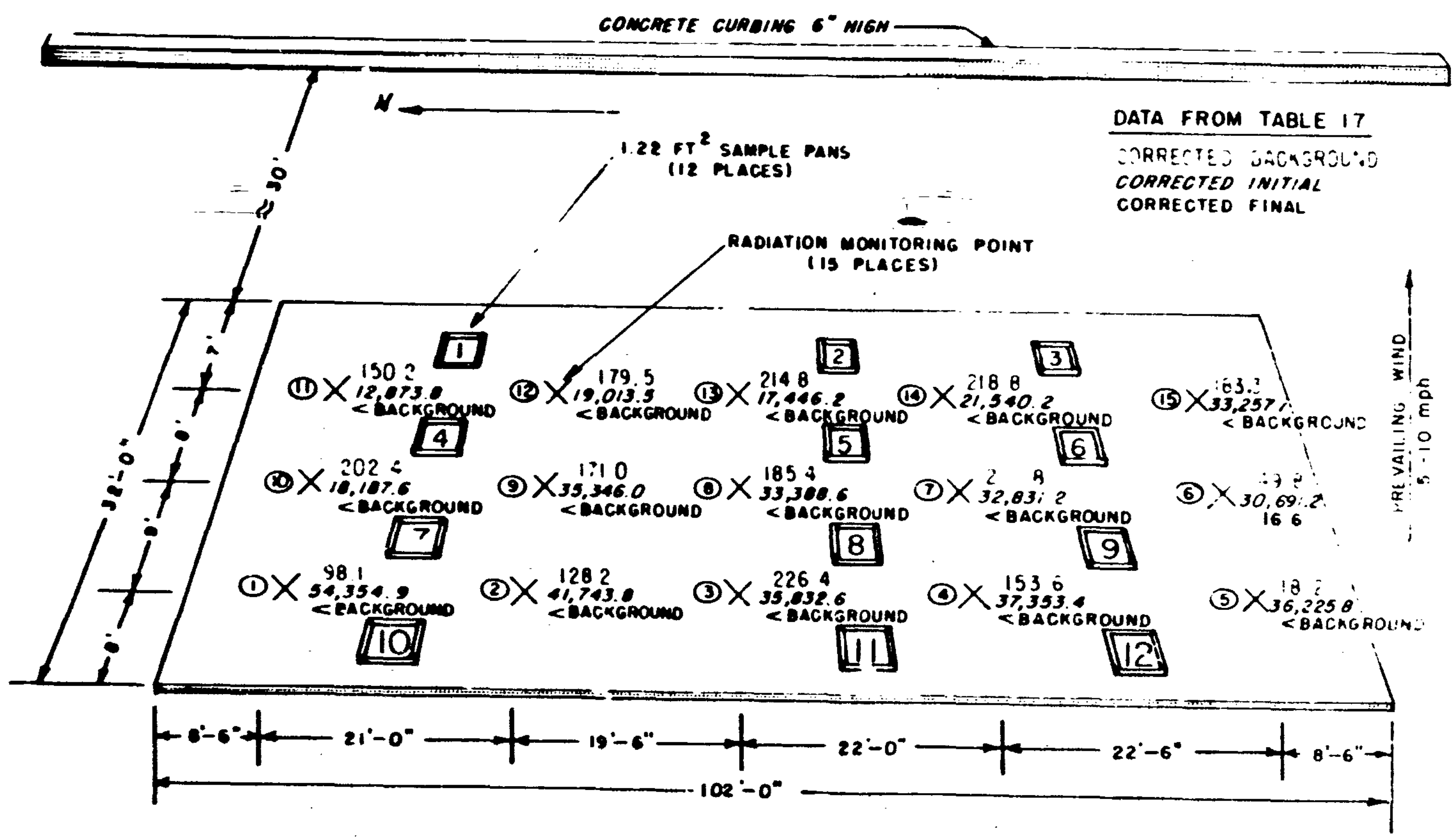

Figure 22. Asphalt test pad and corrected data for remote test #3.

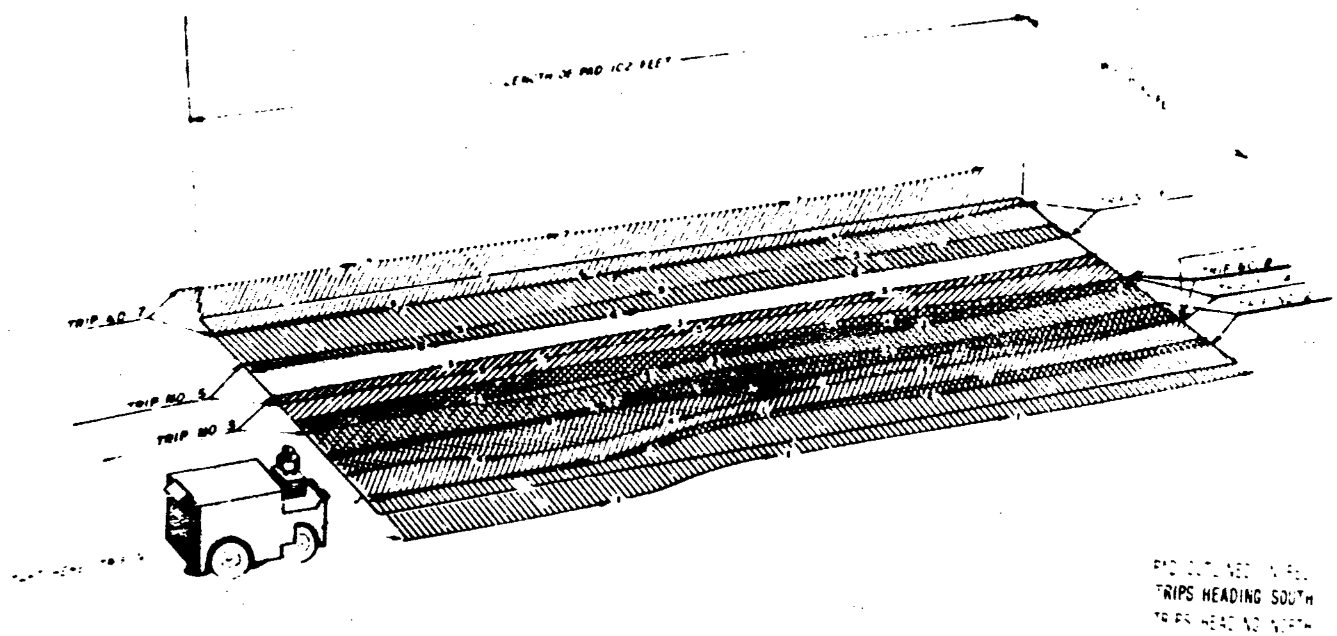

FIGURE 23. SWEEPING PATTERN FOR REMOTE TEST NUMBER 3.

It was noted in this test, as in the others, that every time the vehicle passed by a power transformer, located between the remote control center and the test area, the picture on the monitor became very poor. In fact, the monitor screen was covered with "snow." After the vehicle passed the transformer, there was no longer an effect on the video reception.

It appeared that some difficulties developed in the transmission. It is hard to say whether this was trouble with the push button control panel on the vehicle or with the transmission itself. More and more often the transmission failed to respond to the operator's selection of gears. If the engine was cut off and then restarted, the transmission worked again.

The same difficulties with the hydraulic system were evident in this test as in the other tests. Still, this had no effect on the results.

4. Manual Test #1.

For this test, the pad was contaminated with a density of 22.6 grams per square foot. At a contaminant strength of 8.4 microcuries per gram, the resultant strength of the contaminant was 190 microcuries per square foot.

Data analysis for this test was not complicated by any unusual phenomena. All the lanthanum from previous tests had decayed and the background was back to what could be considered normal.

The corrected data appear in figure 24. In all cases the final count rate was higher than the background.

The efficiency of the sweeper for Manual Test #1 was 99.5 percent. The total operating time was 2.3 minutes. The vehicle was actually sweeping the pad for only 1 minute of this time. The remaining time was used for turning the vehicle around at the end of the pad.

The vehicle was operated in second gear at 2,000 rpm. This was approximately 9.5 mph. Five sweeping passes were normally sufficient to decontaminate the pad; however, seven were used in all three tests. The last two passes were used to clean up small areas of contaminant that had been missed.

Figure 25 is a layout of the approximate pattern the vehicle traced while decontaminating the pad. This pattern was about the same for all three manual tests.

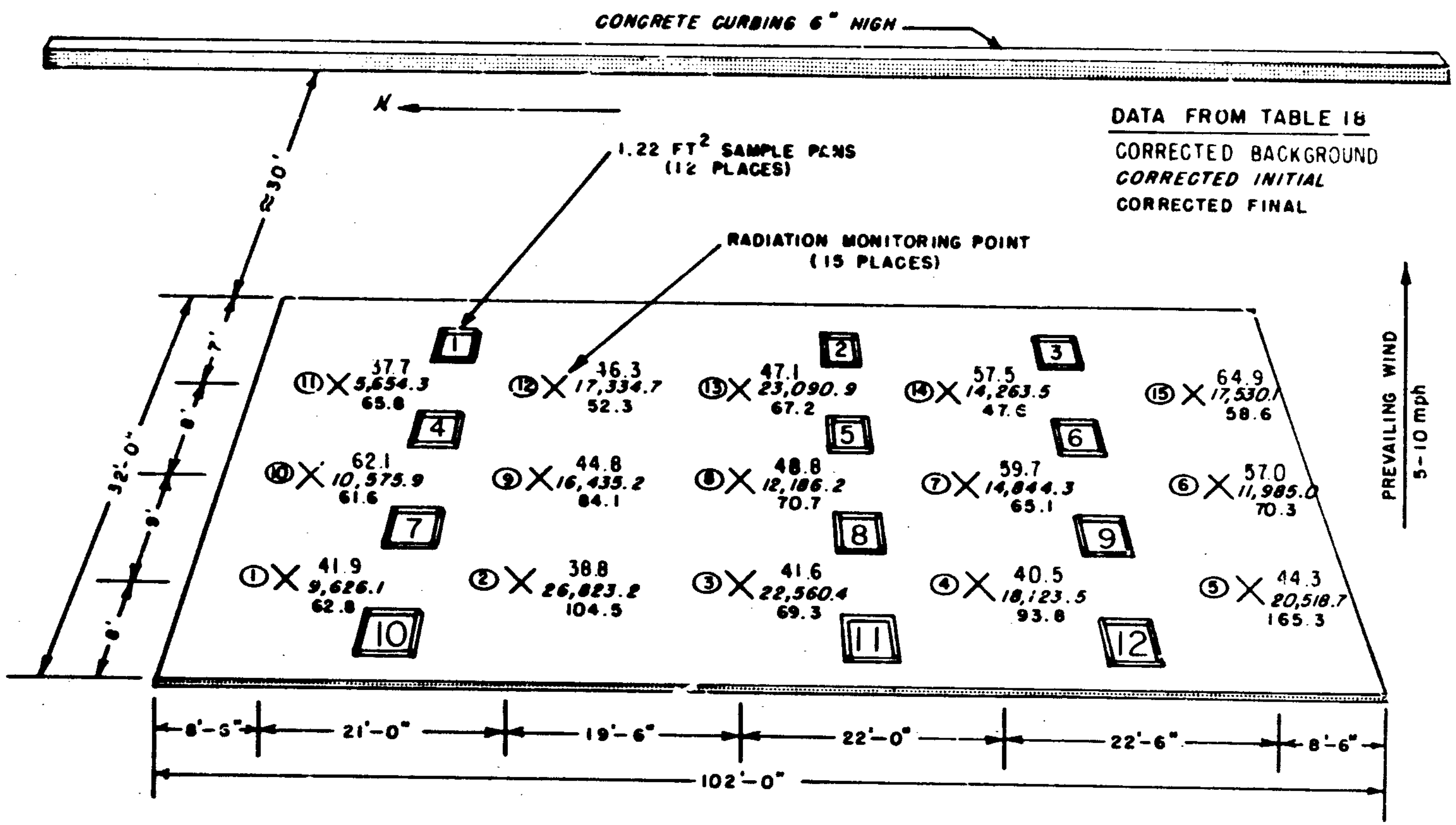

Figure 24. Asphalt test pad and corrected data for manual test #1.

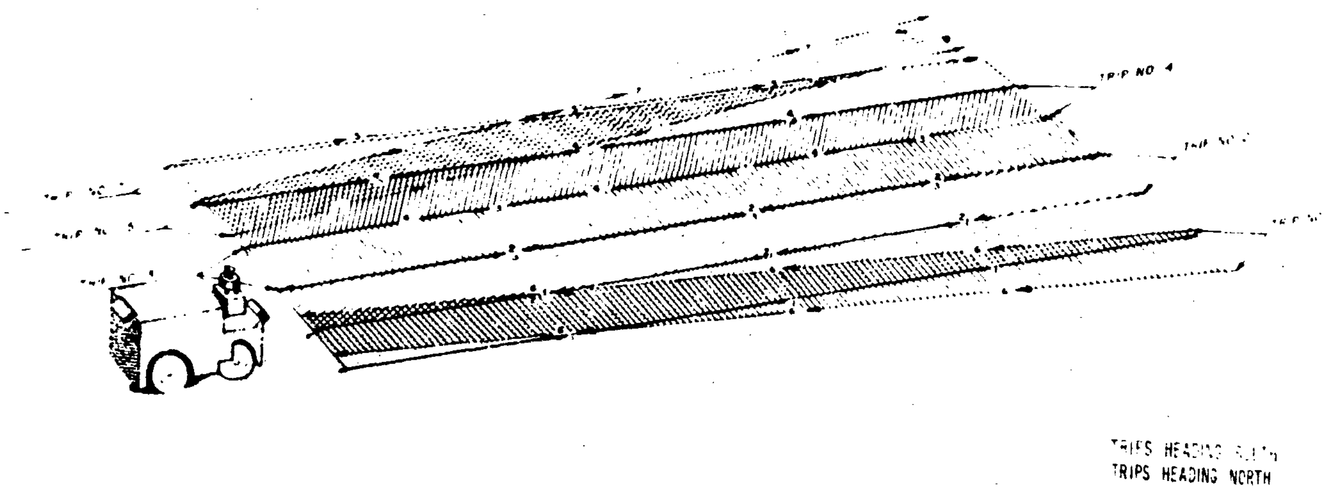

FIGURE 25. ASPHALT TEST PAD AND CORRECTED DATA FOR MANUAL TEST NUMBER 1, 2, AND 3.

5. Manual Test #2.

The pad for this test was contaminated to a higher concentration than for the previous test. Approximately 40.6 grams per square foot of mixture containing 6.1 microcuries per gram were used. This totaled 248 microcuries per square foot or 0.81 curies over the entire pad. The same batch of contaminant that was used for the previous test was used for this test.

As can be seen by comparing the background data of figures 24 and 26, the background increased sharply from 21 June to 22 June. About half of this background is a result of the residual contaminant. If it is assumed that the true background remained constant from 21 to 22 June, then the background due to the residual La-140 was constantly decaying during the test. This was assumed in the analysis of the data.

This was the only test in which the wind was from the East rather than from the West. The wind was only 0-5 mph so it actually had no effect on the data.

Only at two stations did the final count rate appear less than the background. The efficiency for this test, 99.8 percent, was determined by using the data from all 15 stations where data were recorded.

The total operating time for this test was 2.5 minutes. The actual decontamination time was only 52 seconds. Again, seven sweeping passes were made. The same speed was used for this test as for Manual Test #1.

6. Manual Test #3.

The pad was contaminated with an aggregate density of 38.4 grams per square foot. At a contaminant strength of 5.9 microcuries per gram, the resultant strength of the contaminant was 227 microcuries per square foot.

The corrected data for this test appear in figure 27. In all cases except one, the final count rate was greater than background.

The efficiency for this test was 99.8 percent. The total operating time and sweeping time were the same as in Test #2, as were the number of sweeping passes and vehicle operating speed.

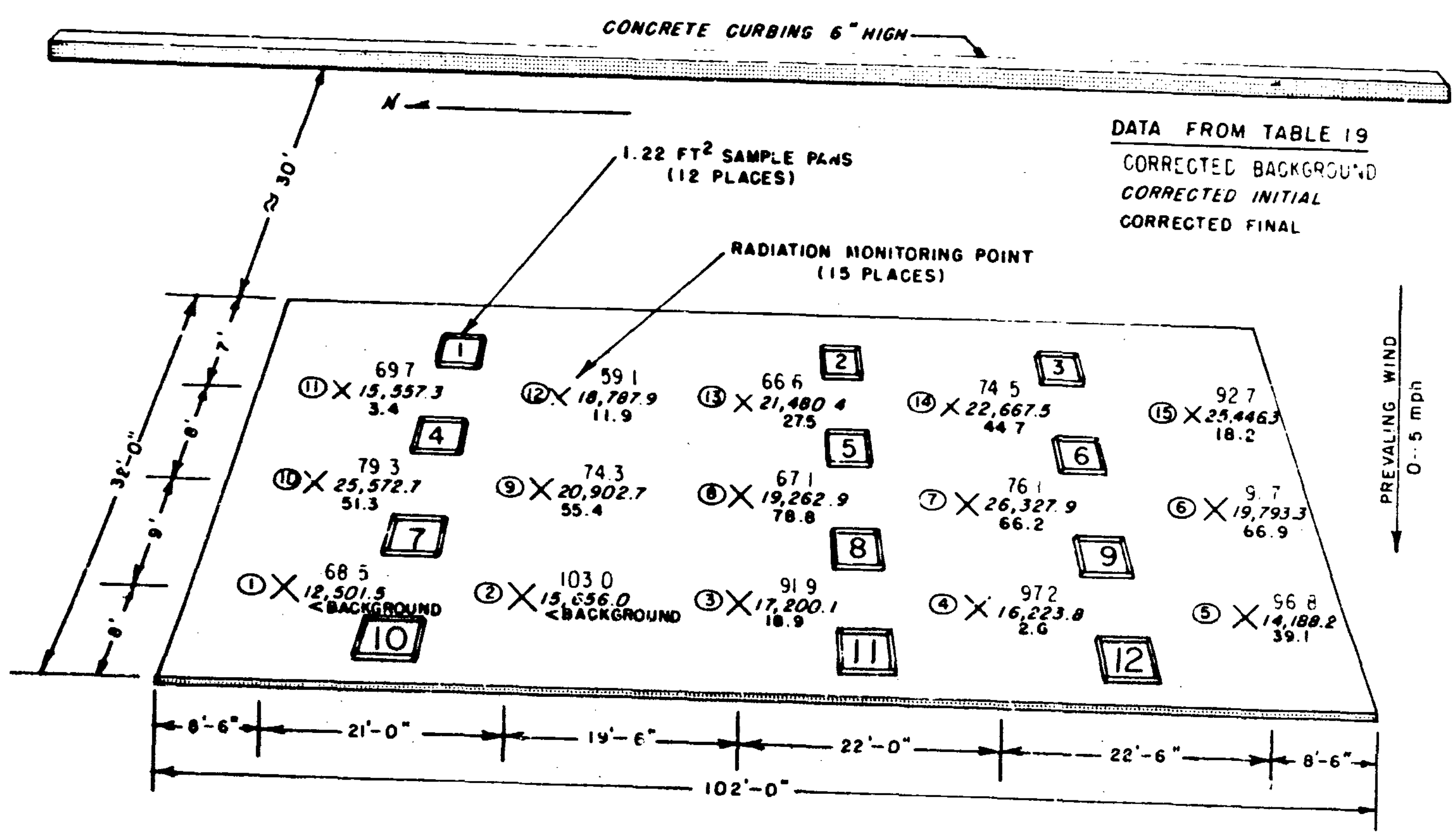

Figure 26. Asphalt test pad and corrected data for manual test #2.

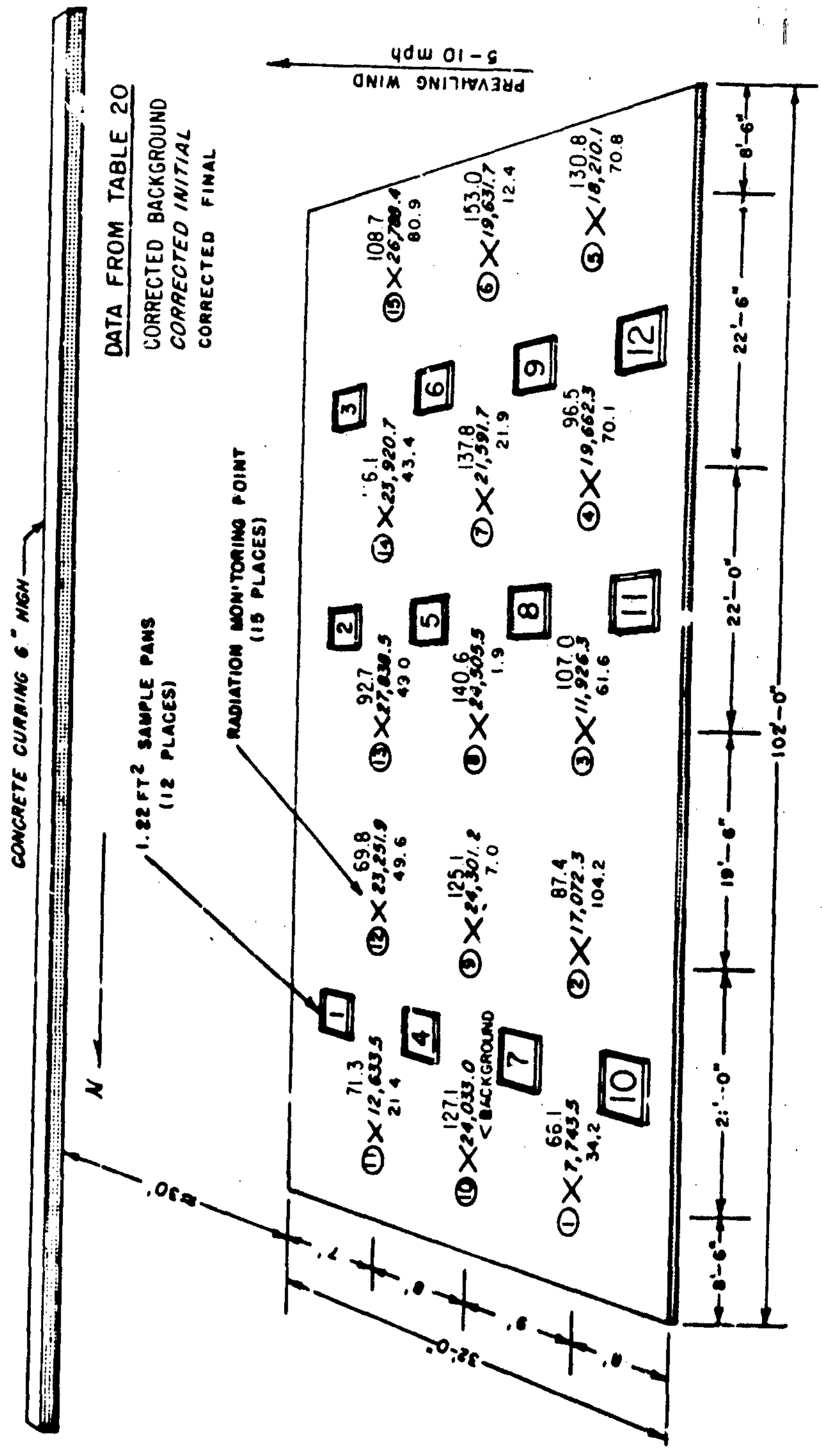

Figure 27. Asphalt test pad and corrected data for manual test #3.

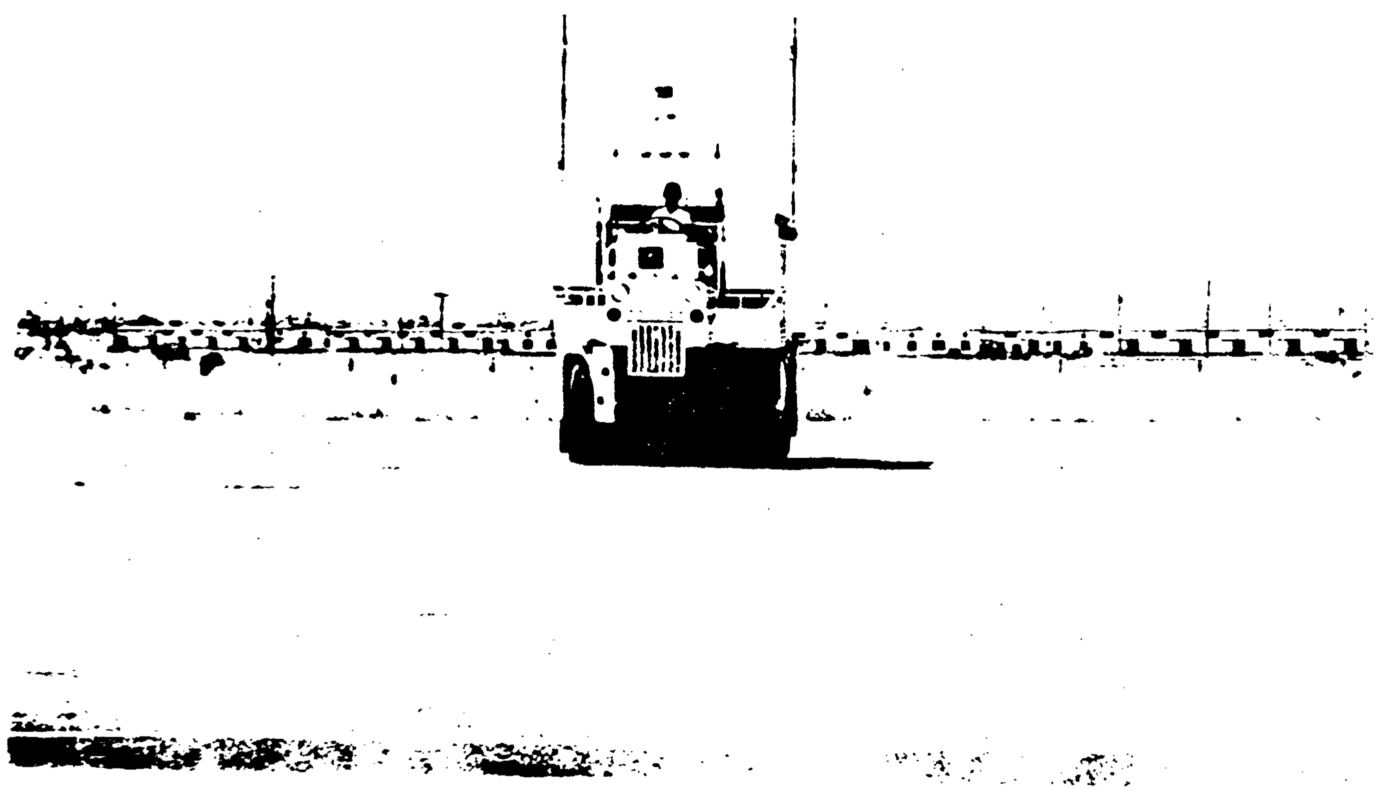

Figure 28. Contaminated test area with vehicle in place.
US Navy Photo

V. CONCLUSIONS.

Based on data obtained with the ARDC-Tennant Model 100DS vacuum sweeper at Camp Parks, California, in June 1960, it is concluded that efficiency of decontamination by remote methods is equal to manual methods.

These tests were conducted on a 3,000-square-foot asphalt area using a dry fallout simulant. The conclusions are based on six tests—three manually operated and three remotely operated. The average efficiency of the sweeper for both the manual and remote tests was 99.7 percent.

Actual decontamination time was about two times greater for remote operation than for manual operation. This ratio can be reduced by refinements in the operation of the sweeper and by increased proficiency of the remote operator.

VI. RECOMMENDATIONS.

1. The prototype vehicle should be consigned to the appropriate agency for further feasibility testing and modification if the USAF has a requirement for such a vehicle.

2. The vehicle should be investigated for use at USAF installations as a standard sweeper to replace or supplement present sweepers. For routine non-emergency sweeping, the sweeper could be used for jet aircraft ramps, runways, taxiways, hangars, and similar high-cleanliness areas. Because of the tremendous velocity and volume of air handled by jet turbines, sand, dirt, and similar foreign objects can cause serious damage involving costly repairs. The sweeper, while immediately ready for emergency decontamination, can be used daily at USAF installations. The "plus 99 percent" sweeping efficiency of the vehicle appears to be a sensible and economical preventive maintenance technique.

3. The vehicle, if considered for immediate procurement only as a runway-type sweeper, should be designed so that it can be modified for use as a decontamination sweeper at a later date at the least possible cost in time and money.

APPENDIX A
RAW DATA

In this appendix appear the raw data collected at the Camp Parks test site. Tables 6, 7, and 8 are the raw data collected during the three remote control tests. Tables 9, 10, and 11 are the raw data collected during the three manual tests.

These data are recorded in counts per minute (cpm) and were measured with a mobile shielded gamma detector unit utilizing a NaI scintillation crystal.

The "station" column refers to the locations on the test pad where these readings were recorded (see figure 17). Each column of data includes the time that the counting was started and the time that it ended. The mean time for each series of measurements is recorded at the bottom of each table.

Tables 12 and 13 contain the raw data of weights and activities of the contaminant as determined by scales and a 4π ion chamber respectively. The "Sample Pan Number" refers to the location of the sample pan on the test pad. (See figure 17.)

Dose rate data were recorded at nine positions on the vehicle with a PDR-27A radiac instrument. These data were recorded for four of the six tests and appear in table 14. Correction factors have not been applied to these data. They present the relative dose rate at selected positions on the vehicle under various circumstances.

Table 6

MOBILE SHIELDED DETECTOR READINGS
TAKEN 14 JUNE 1960, REMOTE TEST #1

Time Start	0955		1230		1450	
Ra Std	14898	14265	11083	10641	11454	11906
Station*	**Background**		**Initial**		**Final**	
1	66	46	26671	26639	215	263
2	31	27	81597	81088	298	304
3	35	31	55700	55652	314	294
4	23	59	45881	46016	215	235
5	18	39	79023	79012	147	152
6	30	31	62407	62169	178	209
7	31	29	56390	55805	313	274
			55338			
8	23	33	95242	98588	382	395
9	15	30	76697	77618	379	423
10	22	27	56167	56216	324	339
11	29	22	25694	25218	501	439
12	22	21	49375	50242	665	653
13	23	40	33788	32462	722	712
14	31	23	30741	30665	582	557
15	23	36	46804	47183	230	249
Ra Std	12525	12503	11454	11906	7585	7596
Time End	1040		1345		1540	

Mean Time

Background - 1015
Initial - 1330
Final - 1515

*See Figure 17

Table 7

MOBILE SHIELDED DETECTOR READINGS
TAKEN 16 JUNE 1960, REMOTE TEST #2

Time Start	1000		1125		1330	
Ra Std	10967	10972	10899	11010	10588	10788
Station*	Background		Initial		Final	
1	238	253	19176	16471	127	135
2	296	308	34471	34440	203	204
3	378	391	35311	34698	356	340
4	279	292	31661	30997	195	188
5	225	242		26721	172	169
6	276	277	44084	42299	212	230
7	568	539	43316	43624	398	388
8	284	260	18494	18636	270	281
9	326	271	30517	24175	220	225
10	281	283	13623	13467	259	234
11	205	203	27994	25003	284	247
12	339	264		13792	295	336
13	303	326		18909	318	319
14	319	273	10000	23586	319	299
15	270	242	21644	21640	294	248
Ra Std	10[illegible]	11010	10987	10976	9449	9507
Time End	1045		1215		1425	

Mean Time
Background - 1025
Initial - 1155
Final - 1400

*See Figure 17

Table 8

MOBILE SHIELDED DETECTOR READINGS
TAKEN 17 JUNE 1960, REMOTE TEST #3

Time Start	0825		0955		1210	
Ra Std	10155	10159	9445	9356	8530	8451
Station*	**Background**		**Initial**		**Final**	
1	79	118	50597	50995	87	73
2	127	132	39604	38955	97	86
3	238	219	34146	33889	100	104 89
4	166	141	35604	35566	79	79
5	119	117	34778	34580	97	94
6	144	153	29437	29758	124	145
7	222	234	31487	32336	164	163
8	179	187	32393	32799	146	111
9	175	160	34623	34746	91	107
10	211	184	18428	17701	130	120
11	143	148	12842	12898	91	95
12	181	167	19124	19034	122	131
13	215	198	17327	17673	138	147
14	210	209	21878	22079	172	139
15	193	156	33852	34047	144	131
Ra Std	9445	9356	10414	10298	8217	8530
Time End	0910		1040		1310	

Mean Time
Background - 0850
Initial - 1020
Final - 1245

*See Figure 17

Table 9

MOBILE SHIELDED DETECTOR READINGS
TAKEN 21 JUNE 1960, MANUAL TEST #1

Time Start	0826		0950		1430	
Ra Std	11969	11928	12265	12349	11146	11171
Station*	Background		Initial		Final	
1	42	43	9754	10240	89	97
2	49	30	28328	27446	119	127
3	40	45	23458	23662	84	106
4	41	41	18702	19319	104	121
5	39	51	21666	21551	166	179
6	64	52	12786	12627	106	105
7	61	61	15967	15614	95	110
8	43	57	13085	12949	97	96
9	42	51	17505	17706	107	98
10	49	79	11455	11368	93	105
11	32	47	6163	6098	86	76
12	49	47	18814	18792	87	67
13	52	47	25111	25161	83	92
14	73	47	15615	15632	85	77
15	52	84	19131	19422	95	93
Ra Std	12505	12539	13102	13166	9277	9345
Time End	0915		1045		1515	

Mean Time
Background - 0845
Initial - 1015
Final - 1500

*See Figure 17

Table [illegible]

MOBILE SHIELDED DETECTOR READINGS
TAKEN 22 JUNE 1960, [illegible] TEST #2

Time Start	0830		1000		1115	
Ra Std	10475	10552	10414	10442	10550	10515
Station*	Background		Initial		Final	
1	71	66	12440	12599	76	56
2	101	106	15746	15863	82	96
3	98	85	17601	17148	105	112
4	99	103	16568	16359	98	97
5	103	88	14395	14511	134	132
6	83	96	20258	20097	156	153
7	74	74	26864	26880	129	149
8	57	73	19674	19787	143	140
9	72	71	21667	21282	125	127
10	70	81	26147	26531	145	108
11	65	68	16041	16146	74	67
12	54	58	19729	19207	66	72
13	62	64	22375	22273	83	96
14	74	66	23609	23656	109	121
15	92	81	26463	26776	102	112
Ra Std	9749	9712	10864	11099	10077	10321
Time End	0920		1100		1205	

Mean Time
Background - 0900
Initial - 1030
Final - 1145

*See Figure 17

Table 11

MOBILE SHIELDED DETECTOR READINGS
TAKEN 22 JUNE 1960, MANUAL TEST #3

Time Start	1120		1345		1445	
Ra Std	10550	10515	9896	9955	9866	9713
Station*	Background		Initial		Final	
1	76	58	7425	7282	96	88
2	82	96	16032	16256	178	169
3	105	112	11296	11362	157	147
4	98	97	18631	18480	151	146
5	134	132	17187	17231	158	199
6	156	153	18335	18759	145	147
7	129	149	20740	19964	150	129
8	143	140	23087	23038	144	103
9	125	127	22904	22770	122	105
10	145	108	22855	22280	98	104
11	74	67	11665	12049	90	67
12	66	72	21799	21[illegible]92	102	99
13	85	96	26190	25852	121	116
14	109	121	22356	22390	128	138
15	102	112	24718	25308	167	147
Ra Std	10077	10321	9866	9713	8750	8678
Time End	1205		1435		1530	

Mean Time
Background - 1145
Initial - 1415
Final - 1510

*See Figure 17

Table 12

SAMPLE PAN WEIGHTS

Sample Pan Number*	Remote Test 1	Remote Test 2	Remote Test 3	Manual Test 1	Manual Test 2	Manual Test 3
	Net Weight in Grams per 1.22 Square Feet					
1	60.7	117.5	40.0	24.8	33.8	87.8
2	22.9	41.5	60.0	27.4	34.4	36.4
3	26.2	59.4	—	52.5	57.1	45.1
4	33.6	43.1	79.0	42.1	72.4	48.5
5	23.8	46.8	70.9	32.0	52.2	45.0
6	49.2	86.7	56.2	13.0	41.9	36.5
7	36.2	77.3	66.5	15.5	34.1	44.9
8	37.1	51.7	65.6	31.5	56.0	43.8
9	20.9	76.0	87.3	21.4	67.4	52.4
10	22.3	79.3	50.6	23.8	46.8	30.0
11	23.3	76.2	83.1	23.7	56.7	48.8
12	33.9	79.4	58.5	24.7	42.6	43.5
Wind (mph)	0-5	15-20	5-10	5-10	0-5 east	5-10

*See Figure 17

Table 13

SPECIFIC ACTIVITIES FROM SAMPLE PANS

Date and time data were counted.

Test Number	14 Jun 60 1610	15 Jun 60 1535	16 Jun 60 1525	17 Jun 60 1445	21 Jun 60 1335	22 Jun 60 1345	22 Jun 60 1545	23 Jun 60 1545
	Activity in microcuries/gram							
Remote #1	20.0	13.0	9.3	6.3				
	18.7	12.5	8.7	5.8				
	19.0	12.5	8.3	5.6				
Remote #2		—	8.5	5.7				
		—	9.0	6.0				
		—	9.1	6.1				
Remote #3		—	—	5.7				
		—	—	5.8				
		—	—	5.8				
Manual #1					8.00	5.10	—	3.35
					7.80	5.00	—	3.30
					8.05	5.10	—	3.40
Manual #2					—	—	5.10	3.60
					—	—	5.80	3.80
					—	—	5.60	3.70
Manual #3					—	—	5.40	3.60
					—	—	5.80	3.80
					—	—	5.60	3.80

Table 14

DOSE RATE READINGS ON VEHICLE
RECORDED WITH PDR-27A

Position on Vehicle*	Remote Test #1 - 14 June 1960			Remote Test #2 - 16 June 1960		
	Before Test	Full Hopper	Empty Hopper	Before Test	Full Hopper	Empty Hopper
	Dose Rate (mr/hr)			Dose Rate (mr/hr)		
1	0.03	28	0.3	0.1	27	1.1
2	0.03	210	1.6	1.8	28	2.[illegible]
3	0.03	200	3.0	1.7	310	2.6
4	0.03	500+	9.0	4.8	390	7.0
5	0.03	500+	11.0	4.8	500+	8.0
6	0.03	220	3.3	2.4	410	3.2
7	0.03	100	1.6	1.1	70	2.3
8	0.03	2.5	0.1	0.06	1.0	0.7
9	0.03	—	—	—	—	10.0

Position on Vehicle*	Manual Test #2 - 22 June 1960 AM			Manual Test #3 - 22 June 1960 PM		
	Before Test	Full Hopper	Empty Hopper	Before Test	Full Hopper	Empty Hopper
	Dose Rate (mr/hr)			Dose Rate (mr/hr)		
1	0.15	17	0.45	0.6	12	0.8
2	0.35	80	1.6	1.6	48	1.9
3	0.3	70	1.6	1.8	90	2.3
4	1.3	500+	3.8	4.8	450	7.0
5	1.8	500+	6.0	5.0	470	9.0
6	0.8	100	2.0	1.8	110	3.3
7	0.4	50	1.3	1.1	40	1.6
8	0.0[illegible]	5	0.6	0.2	4	0.6
9	2.8	—	10.0	6.0	—	10.0

*1 - Center of driver's seat
2 - Left front side of vehicle on louvered doors
3 - Left rear side of vehicle above wheel well
4 - Left rear of vehicle on hopper
5 - Right rear of vehicle on hopper
6 - Right rear side of vehicle above wheel well
7 - Right front side of vehicle on louvered doors
8 - Front of vehicle between headlights
9 - Inside hopper

APPENDIX B
ANALYSIS OF DATA

In this appendix appear the data collected during the six tests. These data have been corrected for calibration, background and decay where appropriate.

Two count rate readings were recorded at each station. These have been averaged and correction applied to the averages. They appear as one reading in the tables of this appendix.

For decay corrections, the mean times were used and all readings were decayed to the mean time of the "initial" readings. Decay corrections were applied only where it was considered that sufficient time had elapsed for the lanthanum to change significantly.

Table 15

CORRECTED MOBILE SHIELDED DETECTOR READINGS FOR ASPHALT AREA TESTS WITH TENNANT MODEL 100DS SWEEPER

14 JUNE 1960 - REMOTE TEST #1

Starting Time	0955	1230	1450
Station	Corrected* Background (cpm)	Corrected** Initial (cpm)	Corrected*** Final (cpm)
1	56.6	35581.4	259.8
2	29.6	108252.4	383.2
3	34.0	73754.0	395.6
4	42.7	60583.3	283.2
5	29.4	103766.6	195.6
6	31.9	81423.1	267.3
7	32.2	72666.8	434.2
8	30.3	125617.7	604.8
9	25.1	99514.9	646.8
10	27.6	72135.4	543.6
11	28.9	32512.1	799.5
12	24.7	63356.3	1161.1
13	36.3	41919.7	1290.4
14	30.9	38678.1	1047.1
15	33.5	58938.5	430.8
Averages	32.9	107596.7	582.9

* Corrected for Radium Standard Only
** Corrected for Radium Standard and Background
*** Corrected for Radium Standard, Background and Decay

Table 16

CORRECTED MOBILE SHIELDED DETECTOR READINGS FOR ASPHALT AREA TESTS WITH TENNANT MODEL 100DS SWEEPER 16 JUNE 1960 - REMOTE TEST #2

Starting Time	1000	1125	1330
Station	Corrected* Background (cpm)	Corrected** Initial (cpm)	Corrected*** Final (cpm)
1	240	17606.8	< Background
2	294	34200.6	< Background
3	375	34663.6	< Background
4	280	31074.0	< Background
5	229	26509.1	< Background
6	271	42941.7	< Background
7	542	429'1.9	< Background
8	267	18301.0	19.6
9	293	27049.2	< Background
10	277	13264.2	< Background
11	201	26586.7	75.6
12	199	13585.3	129.7
13	310	18585.8	21.4
14	291	16487.9	32.2
15	252	21348.8	29.5
Averages	288.1	25676.4	51.3

* Corrected for Radium Standard and Decay
** Corrected for Radium Standard and Background
*** Corrected for Radium Standard, Background and Decay

Table 17

CORRECTED MOBILE SHIELDED DETECTOR READINGS FOR ASPHALT AREA TESTS WITH TENNANT MODEL 100DS SWEEPER

17 JUNE 1960 - REMOTE TEST #3

Starting Time	0825	0955	1210
Station	Corrected* Background (cpm)	Corrected** Initial (cpm)	Corrected*** Final (cpm)
1	98.1	54354.9	< Background
2	128.2	41743.8	< Background
3	226.4	35832.6	< Background
4	153.6	37353.[illegible]	< Background
5	118.2	36225.8	< Background
6	149.8	30691.2	16.6
7	229.8	32831.2	< Background
8	185.4	33388.6	< Background
9	171.0	35346.0	< Background
10	202.4	18187.6	< Background
11	150.2	12873.8	< Background
12	179.5	19013.5	< Background
13	214.8	17446.2	< Background
14	218.8	21540.2	< Background
15	183.3	33257.7	< Background
Averages	174.0	30672.4	16.6

* Corrected for Radium Standard and Decay
** Corrected for Radium Standard and Background
***Corrected for Radium Standard, Background and Decay

Table 18

CORRECTED MOBILE SHIELDED DETECTOR READINGS FOR ASPHALT AREA TESTS WITH TENNANT MODEL 100DS SWEEPER 2[illegible] JUNE 1960 - MANUAL TEST #1

Starting Time	0826	0950	1430
Station	Corrected* Background (cpm)	Corrected** Initial (cpm)	Corrected*** Final (cpm)
1	41.9	9620.1	62.8
2	38.8	26823.2	104.5
3	41.6	22560.4	69.3
4	40.5	18123.5	93.8
5	44.3	20518.7	165.3
6	57.0	11985.0	70.3
7	59.7	14844.3	65.1
8	48.8	12186.2	70.7
9	44.8	16435.2	84.1
10	62.1	10575.9	61.6
11	37.7	5654.3	65.8
12	46.3	17334.7	52.3
13	47.1	23090.9	67.2
14	57.[illegible]	14263.5	47.6
15	64.9	17530.1	58.6
Averages	48.9	16103.4	75.9

* Corrected for Radium Standard Only
** Corrected for Radium Standard and Background
**Corrected for Radium Standard, Background and Decay

Table 19

CORRECTED MOBILE SHIELDED DETECTOR READINGS FOR ASPHALT AREA TESTS WITH TENNANT MODEL 100DS SWEEPER

22 JUNE 1960 - MANUAL TEST #2

Starting Time	0830	1000	1115
Station	Corrected* Background (cpm)	Corrected** Initial (cpm)	Corrected*** Final (cpm)
1	68.5	12501.5	< Background
2	103.0	15656.0	< Background
3	91.9	17200.1	18.9
4	97.2	162[illegible]3.8	2.6
5	96.8	141[illegible]8.2	39.1
6	91.7	19793.3	66.9
7	76.1	26327.9	66.2
8	67.1	19262.9	78.8
9	74.3	20902.7	55.4
10	79.3	25572.7	51.3
11	69.7	15557.3	3.4
12	59.1	18787.9	11.9
13	66.6	21480.4	27.5
14	74.5	22667.5	44.7
15	92.7	25446.3	18.2
Averages -	80.6	19437.9	32.3

* Corrected for Radium Standard and Decay
** Corrected for Radium Standard and Background
***Corrected for Radium Standard, Background and Decay

Table 20

CORRECTED MOBILE SHIELDED DETECTOR READINGS FOR ASPHALT AREA TESTS WITH TENNANT MODEL 100DS SWEEPER
22 JUNE 1960 - MANUAL TEST #3

Starting Time	1120	1345	1445
Station	Corrected*	Corrected**	Corrected***
1	66.1	7743.5	34.2
2	87.4	17072.3	104.2
3	107.0	11926.3	61.6
4	96.5	19662.3	70.1
5	130.8	18210.1	70.8
6	153.0	19631.7	12.4
7	137.8	21591.7	21.9
8	140.6	24505.5	1.9
9	125.1	24301.2	7.0
10	127.1	24033.0	< Background
11	71.3	12633.5	21.4
12	69.8	23251.9	49.6
13	92.7	27838.5	49.0
14	116.1	23920.7	43.4
15	108.7	26788.4	80.9
Averages	101.4	20207.3	41.9

* Corrected for Radium Standard and Decay
** Corrected for Radium Standard and Background
***Corrected for Radium Standard, Background and Decay

Table 21

SAMPLE PAN WEIGHTS

Sample Pan Number*	Remote Test 1	Remote Test 2	Remote Test 3	Manual Test 1	Manual Test 2	Manual Test 3
			Net weight in grams per square foot			
1	49.8	96.3	32.8	20.5	27.7	71.9
2	18.8	34.0	49.2	22.5	28.2	29.6
3	21.5	48.7	18.4	43.0	46.8	36.9
4	27.5	35.3	64.8	34.5	59.3	39.8
5	19.5	38.4	58.1	24.6	42.8	36.9
6	40.0	71.0	46.0	10.7	33.5	29.9
7	29.7	63.4	54.5	12.7	27.9	36.8
8	30.4	42.4	53.8	25.8	45.9	35.9
9	17.1	62.5	71.6	17.5	55.2	42.9
10	18.3	65.0	41.5	19.5	38.4	24.6
11	18.9	62.5	68.1	19.4	46.5	40.0
12	27.8	65.1	47.9	20.2	34.9	35.7
Averages	26.6	57.0	50.6	22.6	40.6	38.4

*See Figure 17

Table 22

SPECIFIC ACTIVITIES FROM SAMPLE PANS

Test Number	14 Jun 60 1610	15 Jun 60 1535	16 Jun 60 1525	17 Jun 60 1445	21 Jun 60 1335	22 Jun 60 1345	22 Jun 60 1545	23 Jun 60 1545
	Date and Time Data Were Counted — Corrected Activity in Microcuries/Gram							
Remote #1	21.3	20.6	22.1	22.5				
	19.9	19.8	20.7	20.7				
	20.2	19.8	19.8	20.0				
Remote #2	—	—	9.1	9.0				
	—	—	9.7	9.5				
	—	—	9.8	9.7				
Remote #3	—	—	—	6.2				
	—	—	—	6.3				
	—	—	—	6.3				
Manual #1					8.6	8.2	—	8.6
					8.4	8.1	—	8.5
					8.7	8.2	—	8.7
Manual #2					—	—	5.6	6.0
					—	—	6.4	6.3
					—	—	6.2	6.1
Manual #3					—	—	5.4	5.6
					—	—	5.8	5.9
					—	—	5.6	5.9

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